ENGINEERS' EXAMINER

The Engineers' Examiner

For the aid of those who wish to obtain an engineer's license, and a guide for self-examination, including

Exhaustive Instructions for Valve-Setting.

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Introductory Note.

This work is not placed before the public as a complete examination, such as many of the catechisms are represented to be, but rather to give the reader an idea of the scope of an examination and the principal subjects covered. It is probable that the average examiner asks more questions, but the information necessary to pass a fair examination for a stationary engineer's license is, we believe, contained in the answers, though in condensed form.

The chapters on valve-setting will be found of great value to the man desiring to prepare for an examination. The requests for copies of The Engineer containing the articles were in so many instances accompanied by the statement that they were desired as an aid to the procurement of a license that it was decided to include the series in the volume. These are placed before the examination because we believe they will interest more readers.

THE PUBLISHERS.

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Engine Valves and their Adjustment.

The Plain D Slide-Valve.

Although the slide-valve is of very simple form, and one of the most familiar types of valve to the average engineer, there are many engineers who do not feel competent to undertake the job of setting it. One reason for this feeling of incompetency lies in the fact that they do not understand the practical working of a slide-valve on its seat—that is to say, they have not a clear idea of the proper position of valve, piston, crank and eccentric, at any part of the stroke, and unless an engineer can picture these positions and have them clearly defined in his mind, he is apt to find valve-setting very much of a puzzle:

A consideration of the relative position of piston to valve at various points in the stroke will be taken up before entering upon the work of setting valves. A clear understanding of the operation of the plain *D* slide-valve is very essential to a complete knowledge of other types.

There are those who instead of studying the working of a valve and learning to set it by a thorough knowledge of its various functions, learn a rule for setting the various types of valves.

In the latter case the information soon becomes unreliable and the degree of accuracy realized in setting a valve is there-

fore in proportion to the clearness with which they can recall the exact wording of the rule. It is hoped that the engineers who will read carefully the following explanations of the working of slide-valves and valve-gears will be able to set any valve without the aid of a rule.

Fig. 1 represents a sectional view of a plain slide-valve and the steam and exhaust ports. The valve is represented as

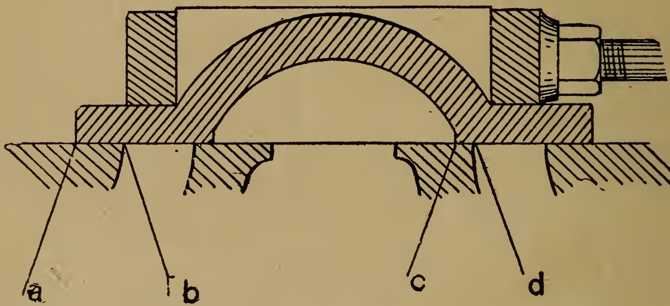


FIG. 1.

occupying a position known as "mid-travel" and when in this position it stands centrally over the ports. The position of mid-travel is also desirable when we wish to measure the outside or steam lap, and the inside or exhaust lap of a valve.

The distance between *a* and *b*, Fig. 1, is called the outside or steam lap, and is the amount or distance that the outer edges of the valve extend beyond the outer edge of the steam ports when occupying the above position, and therefore constitutes the amount the valve *laps* over the ports—hence the term "lap."

Lap is usually measured at one end of the valve only, so that a valve lapping over the steam port at each end to the amount of one-half inch, we say has one-half inch lap. The distance between *c* and *d*, Fig. 1, is called the inside or exhaust lap, and is the distance or amount that the edges of the

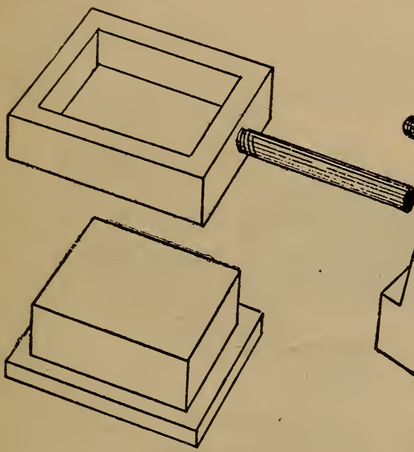


FIG. 2.

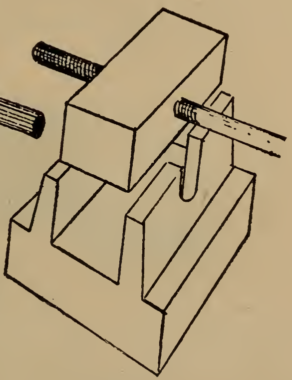


FIG. 3.

cavity extend beyond or *lap* over the inner edges of the steam ports when the valve occupies the position of mid-travel, and is measured at one port only, as in the case of outside lap.

The uses and advantages of outside and inside lap will be described later in connection with the operation of a valve. There are various means employed for attaching the valve

to the valve-stem, one of which is shown in Fig. 2, which consists of a band of iron called a "yoke," the inside of which is made to fit over the upper part of the valve, which has been prepared to receive it as shown in section in Fig. 1. The valve-stem is screwed into the boss on the yoke and secured by a nut as shown.

To move the valve on the stem, it is necessary to loosen the valve-stem in its connection with the eccentric-rod, and also the nut which secures it in the yoke, then turn the valve-

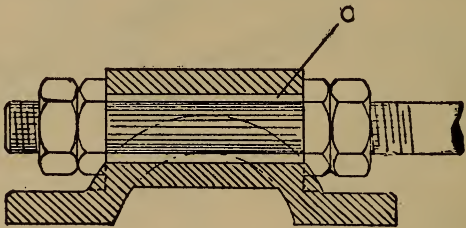


FIG. 4.

stem in the yoke until the desired movement has been obtained. Another method of connecting the valve to the valve-stem is shown in Fig. 3. This consists of an oblong nut of liberal dimensions, screwed on the valve-stem and fitted into the recess in the back of the valve as shown below it. The valve may be moved on the valve-stem by loosening the stem as described above and turning the rod in the nut until the required distance is obtained. A third method often employed is shown in Fig. 4, in which the opening *o* is cored or drilled out somewhat larger than the valve-stem, the latter

being slipped through the opening *o* and the valve screwed to the valve-stem by means of the jamb-nuts as shown.

In the above methods, or in any other method which may be employed for attaching a valve to the valve-stem, the valve must be left free to move in a vertical direction, or at right angles to the valve-stem and with as little lost motion as possible between the yoke, nut or jamb-nuts as the case may be.

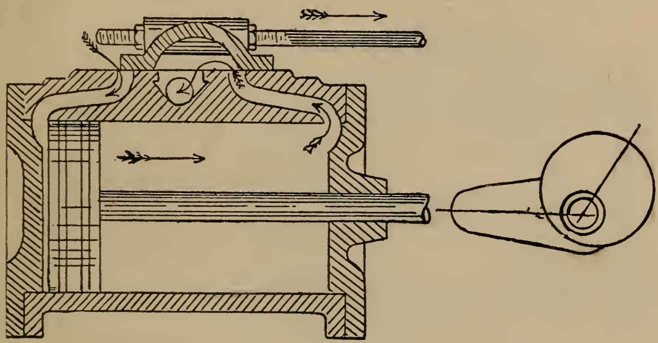


FIG. 5.

The object sought in allowing a valve to thus freely move on the valve-stem is to avoid springing the stem, which would occur as the valve becomes worn after long use, or after having been scraped and refitted to its seat; and also in case there should be an accumulation of water in the cylinder, the water not being compressible, would be forced back through the port by the advancing piston, and were the valve to be rigidly secured to the valve-stem, the valve in being raised

from its seat by the water would badly spring if not break the stem. Having been sprung the stem would bind very hard in the stuffing-box and in a short time would not only put an end to the stem but would destroy the stuffing-box as well.

We will now consider the manner in which a valve admits and exhausts steam to and from the cylinder. Fig. 5 represents the position of the valve and piston at the commence-

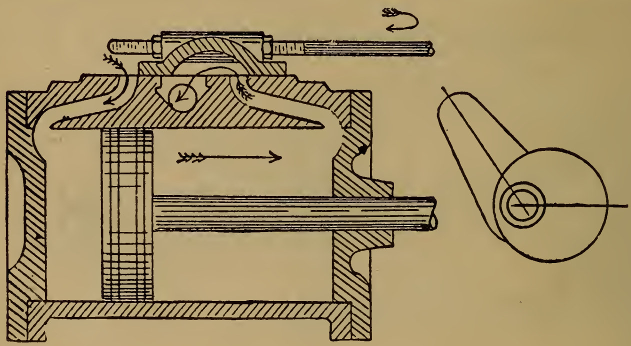


FIG. 6.

ment of the stroke, also the corresponding position of the crank and eccentric.

It will be noticed that the valve has already moved far enough to open the steam port a very little, thus admitting steam to the cylinder and filling the port and clearance space with steam at nearly initial pressure before the crank-pin leaves the dead-center.

The valve has begun its active stroke before the piston

begins its stroke; in other words the valve is in the lead of the piston, therefore the amount that the valve opens the admission port while the crank is on the dead-center is called "lead." Now, as the piston begins to move in the direction of the arrow the valve also moves in the same direction and so continues until arriving at the position shown in Fig. 6, which represents the valve as having completed its stroke

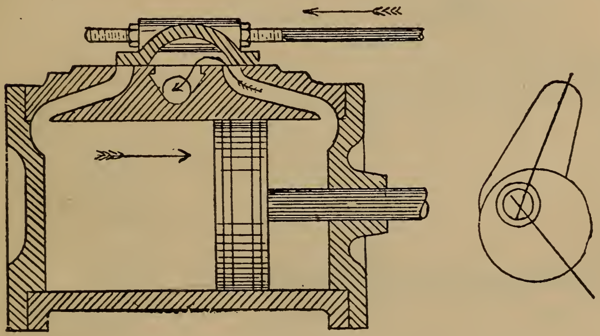


FIG. 7.

and ready to commence its return stroke, also the relative position of the piston in the cylinder and that of the crank and eccentric. The steam port is now wide open and the piston has moved to, approximately, one-quarter stroke, and when it has moved to the point or position indicated in Fig. 7, the valve has then returned a sufficient distance to just close the steam port and produce what is known as "cut-off." The point in the stroke reached by the piston at the moment

cut-off takes place is called the "point of cut-off." In this case it is at about five-eighths stroke. It will be noticed now that the edge of the exhaust cavity in the valve (left-hand side in drawing), Fig. 8, is beginning to open the port to the exhaust and establishing communication between the space *s* in the cylinder and the cavities in the valve and valve seat as

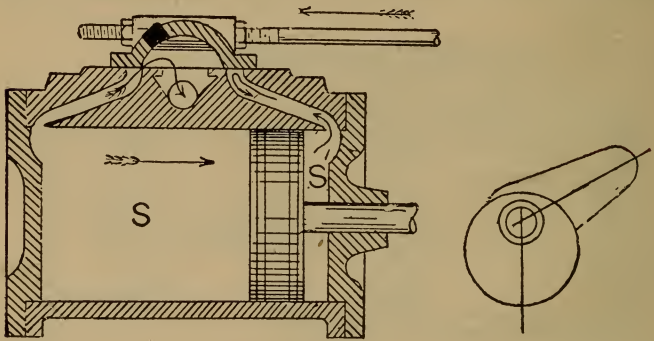


FIG. 8.

indicated by the arrow. The piston has moved from the position shown in Fig. 7 to that shown in Fig. 8 after cut-off took place or occurred; in other words the piston moved through the distance between the positions shown in Figs. 7 and 8 under the *expansive* force of steam alone, or under "expansion" as it is called.

We then understand the term "expansion" to mean the distance the piston moves in the stroke after cut-off takes

place and up to the point where release or exhaust commences. Again referring to Fig. 8 we find that the right-hand edge of the exhaust cavity has just closed the opposite port through which steam from the opposite side (space s') of the piston has been exhausting, and as the piston has not yet reached the end of its stroke, all the steam contained in space s' in the cylinder has not been pushed out by the piston, a portion of this exhaust steam having been entrapped in the cylinder as represented by the arrow.

That portion of the exhaust steam which has been thus shut in the cylinder is crowded or compressed into the clearance space when the piston completes its stroke.

It requires some force to compress this amount of steam into so small a space, therefore the piston meets with resistance as soon as it commences to crowd this steam into the clearance and this resistance increases as the piston advances and until it reaches the end of its stroke. Compressing a portion of the exhaust steam into the clearance as above described is called "compression," and the pressure of the steam thus compressed when the piston reaches the end of the stroke is called the *pressure of compression;* and that point in the stroke reached by the piston at the moment the exhaust port is closed is called the "point of exhaust closure" or the "point of compression."

This completes one full stroke of the piston, the return stroke being made under precisely the same conditions. Let us consider for a moment the object in giving a valve "lead" which you will remember is the amount the valve opens the steam port while the crank is on the dead-center, as shown in Fig. 5. The object sought in giving a valve lead is, primarily,

to cushion the piston at the end of the stroke, thereby effecting an easy reversal of the motion or movement of the reciprocating parts of the engine.

When the piston has advanced to within a short distance of the end of the stroke the valve opens the port a little and admits steam to the cylinder, the pressure rising rapidly and almost to boiler pressure, which has a tendency to stop the piston. The latter in turn imparts this tendency to stop to the crosshead and connecting-rod, thus relieving the crank-pin of much of the strain in bringing these parts to a complete stop at the end of the stroke and again starting them in the opposite direction. Again in giving a valve lead the port is opened wide earlier in the stroke of the piston, and at a point where the connecting-rod and crank occupy a position in which the greatest force is obtained in turning the crank-shaft.

Lead also produces in an engine that quality known among engineers as being "smart," that is, being quick in responding to the action of the valve and especially when starting. The cause of this quality of "smartness" is that when a valve is given lead the port and clearance space are filled with steam at high-pressure before the piston begins its return stroke, therefore there is no waiting for pressure to accumulate behind the piston when the crank-pin moves away from the dead-center.

The object sought in producing compression in an engine cylinder is quite similar to that in giving a valve lead, namely, to arrest the momentum of the reciprocating parts of the engine, or the piston, rod, cross-head and connecting-

rod at the end of the stroke, thus lessening the strain upon the crank-pin as explained above.

But the effect of compression and the method of obtaining the cushioning effect are different from those in the case of lead and therefore "cushion" (lead) and "compression" should not be considered as one and the same thing. The cushioning effect of compression is obtained by shutting in a portion of the *exhaust* steam instead of admitting live steam from the boiler.

At the instant the exhaust valve closes there is no pressure in the cylinder (on the exhaust side of the piston) except that due to the exhaust steam or exhaust pressure.

But, as the piston advances and begins to crowd the steam thus shut in the cylinder into the clearance space, pressure is gradually produced, reaching the maximum when the piston has completed its stroke.

From this it will be understood that, as the pressure gradually increases as the piston advances toward the end of its stroke the cushioning effect must also be gradual, thus bringing the rapidly moving parts of the engine *gradually* to rest at the end of the stroke without a jar or pound. The pressure of compression is very rarely as high as that obtained in the case of lead, for, to increase the pressure of compression up to the initial pressure would require that a greater amount or volume of steam be shut in the cylinder by closing the exhaust port, and in order to do this the exhaust valve would have to close the port very early in the stroke, and the power absorbed in compressing the larger volume of steam to initial pressure would materially lessen the useful work of the engine.

In giving a valve lead in an engine in which the piston is partially cushioned by compression we have but to make up the difference in pressure between that of compression and the initial pressure, hence the lead in this case may be reduced, thus often effecting a saving in steam.

Objects of Outside and Inside Lap.

Fig. 9 represents the position of the valve, piston, crank

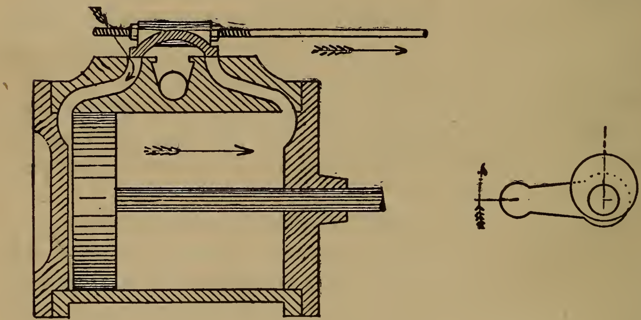


FIG. 9.

and eccentric at the commencement of the stroke, which is to be in the direction indicated by the arrow. The valve in this case has no lap, that is, the outer edges of the valve do not extend beyond the outer edges of the steam ports, nor do the edges of the exhaust cavity in the valve extend beyond the inner edges of the steam ports when the valve occupies the position of mid-travel. Again referring to Fig. 9 we find the valve has opened the admission port a very little, or to the

amount of the "lead," and the center line of the eccentric stands at right angles (or nearly so) to the center line of the crank. Now, as the piston moves in the direction indicated by the arrow, the eccentric, and therefore the valve, also moves in the same direction, and so continues to move until arriving at the position shown in Fig. 10. The admission port is now wide open and the eccentric has reached the dead-center farthest from the cylinder, and is therefore ready to

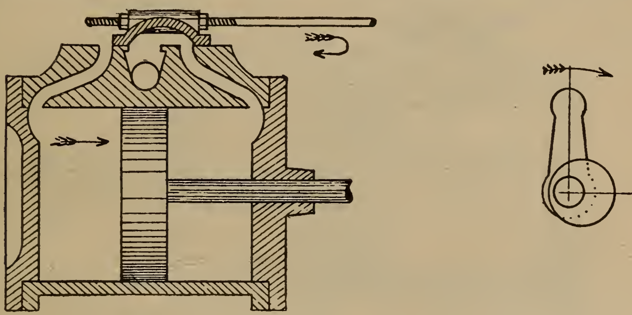


FIG. 10.

commence its return stroke, while the piston has only moved to about one-half stroke.

Fig. 11 shows the piston as having completed its stroke, the valve having just closed the admission port and effected the "cut-off." It will be seen from this that the steam has followed the piston throughout the entire stroke before the cut-off occurred, allowing of no expansion whatever.

The exhaust port is opened at the same instant that the cut-off takes place, exhausting steam at initial pressure into

the atmosphere, no work having been done in the cylinder by expansion—which would result in an enormous waste of steam, for economy in the amount of steam taken from the boiler can only be realized by admitting a certain quantity of steam to the cylinder and allowing it to expand, thus getting out of it all the good (expansive force) there is in it.

An engine having a valve with no steam lap cannot be run at high speed without entailing an additional loss

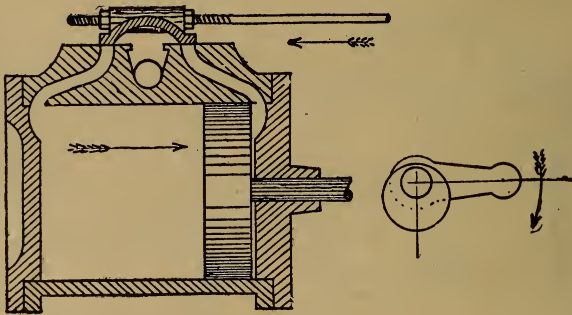


FIG. 11.

(this time in power) due to excessive compression, for the exhaust cavity in the valve cannot be widened beyond that shown in Fig. 11, which would allow the exhaust port to be opened before the piston reached the end of its stroke, allowing a free exhaust to be realized; for, to widen the exhaust cavity would reduce the thickness of the valve at *A*, Fig. 12, and permit live steam to pass from the steam-chest to the exhaust pipe as the valve passed over the port as shown. The drawing in Fig. 5 represents a valve

having lap. The engine is in the same position as in Fig. 9 and the valve also has opened the steam-port to the amount of the lead. So far both cases are identical, but turning to the eccentric we find a change, and instead of its central line standing at right angles to the crank, we find it inclined away from a vertical position. This position is due to the fact that the valve has lap, for if the eccentric in Fig. 5 were to be set in the position shown in Fig. 9. the piston would have to move to about one-half stroke before the valve would open

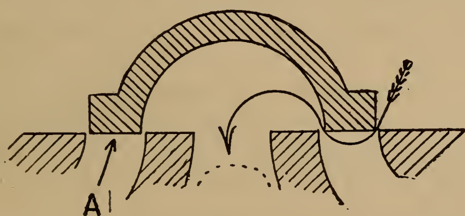


FIG. 12.

the port; therefore, as this would be impracticable, the eccentric must be moved around on the shaft and until it has moved a certain distance beyond the position shown in Fig. 9, which distance is determined by the amount of lap on the valve, and also the amount of lead, for the eccentric must be moved away from a vertical position in order to draw the valve away from its position of mid-travel, and far enough to open the steam port to the amount of the lead.

Many engineers maintain the mistaken idea that there is a particular angle at which an eccentric should be set with reference to the center line of the crank, but upon studying

the foregoing figures it will be plainly seen by most engineers that the angle referred to will and does change with different amounts of lap and lead, and this change may be effected any number of times in almost any engine without seriously impairing its running qualities.

Fig. 6 shows the position of the piston in the cylinder when the port is wide open and the eccentric has now reached its dead-center. By comparing the position of the piston shown in Figs. 6 and 10 it will be seen that the piston has not moved as far in the stroke when the eccentric reaches its dead-center and when the valve has lap as in the former case.

Fig. 7 shows the valve as having completed its stroke in the direction of the arrow, and returned sufficiently to close the admission port, producing "cut-off," which, in this case is at about two-thirds stroke instead of full stroke as in the case of no lap.

Fig. 8 represents the piston as having advanced a little further in the stroke, and after cut-off has occurred or under expansion. The valve is now beginning to open the exhaust port, although the piston has not yet reached the end of its stroke, thus allowing a free exhaust, for by the time the piston reaches the end of the stroke, the valve will have opened the port to the exhaust to nearly one-half the width of the port, while in Fig. 11, the valve was just beginning to open the port to the exhaust when the piston had completed its stroke.

From the foregoing we learn that the object in having lap on a valve is to cause the cut-off to occur earlier in the stroke, or before the piston has completed its stroke, and the advan-

tage to be gained is in allowing the piston to move a certain distance after the supply of steam has been shut off, or under expansion; that is, in shutting off the steam from the cylinder before the piston reaches the end of the stroke, the whole cylinder is not filled with steam from the boiler, but only that portion of the cylinder measured from the commencement of the stroke to the point of cut-off, the remainder of the stroke of the piston being accomplished by the *expansive force* of the steam only. The object in having inside or exhaust lap on a valve (which is rarely to be found in fast running engines) may be understood by referring to Fig. 8. If the width of the exhaust cavity in the valve had been lessened the port would not have been opened to the exhaust until the piston had moved nearly to the end of its stroke.

This would have caused the steam to follow the piston further in the stroke which, under certain conditions, might prove to be an advantage, but we also see that if the width of the cavity had been reduced it would have caused the exhaust port (Fig. 8) to be closed earlier in the stroke, thereby shutting in a larger volume of steam which would have been compressed to a higher pressure than would be desirable in a fast-running engine.

The object of inside lap on a valve then, is to cause the opening of the port to the exhaust to occur later in the stroke and the closing of the exhaust port to occur earlier in the return stroke.

To return for a moment to the advantages gained in having steam lap on a valve:

Many engineers who are without means of obtaining the mean effective pressure, or even the average pressure in an

engine cylinder, still persist in taking the boiler or initial pressure as the mean effective pressure when computing the horse power of an engine.

From the foregoing it will be seen that this method is entirely wrong except in engines having valves with no lap and which, happily, are "few and far between" nowadays. The above method can only be of service and reliable when steam is admitted during the full stroke of the piston, for in this case the mean effective pressure becomes the initial pressure minus the back pressure and the horse power developed would largely exceed that of an engine having a valve provided with lap, the size of the cylinder, speed and initial pressure being the same. To illustrate this point let us assume an engine taking steam full stroke and one in which the cut-off occurs at one-half stroke and note the difference in horse power developed. Diameter of cylinder (in both cases) = ten inches; length of stroke = 18 inches and running at 150 revolutions per minute. Initial pressure = 80 pounds per square inch and back pressure in first case = eight pounds and in second case three pounds (gauge).

The horse power with no lap would be:

$$\frac{PLAN}{33{,}000} = \frac{78.54 \times 3 \times 72 \times 150}{33{,}000} = 77.11 \text{ horse power.}$$

In this formula P = area of the piston, L = length of stroke, A = mean effective pressure and N = number of strokes per minute.

The horse power when cutting off at one-half stroke would be:

$$\frac{PLAN}{33{,}000} = \frac{78.54 \times 3 \times 53.2 \times 150}{33{,}000} = 56.97 \text{ horse power.}$$

The foregoing examples plainly indicate that an engineer who uses by-gone methods in computing the horse power of an engine makes a serious mistake and one which should be looked upon as inexcusable in these days when engineering literature may be had almost for the mere asking.

The above illustration also indicates that an engine having a valve provided with steam or outside lap, requires a larger cylinder than one in which the valve has no lap, in order to develop a given horse power with a given initial pressure—other things being equal. While the larger cylinder would be more costly at the outstart, yet the saving in steam effected by the lap and in turn an earlier cut-off, as previously explained, would in a comparatively short time pay for the increase in the first cost, and after the amount saved had equaled the extra expense of the larger cylinder, the saving would be "clear gain" as long as the engine continued to run.

Adjustment of the Eccentric-Rod and Setting the Valve.

We will now take up the adjustment of the eccentric-rod and method of setting a slide-valve. It may be well to say here, that no valve operated by means of an eccentric and eccentric-rod can be set in a satisfactory manner until the eccentric-rod has been adjusted to the proper length.

This may be understood by referring to Fig. 13 which represents the eccentric of an engine placed on its dead-center nearest the cylinder. It will be noticed that the valve has not fully opened the steam port nearest the crank. This is

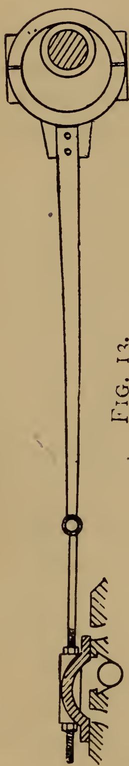


Fig. 13.

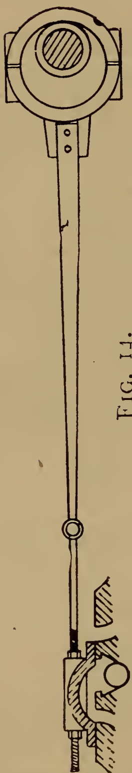


Fig. 14.

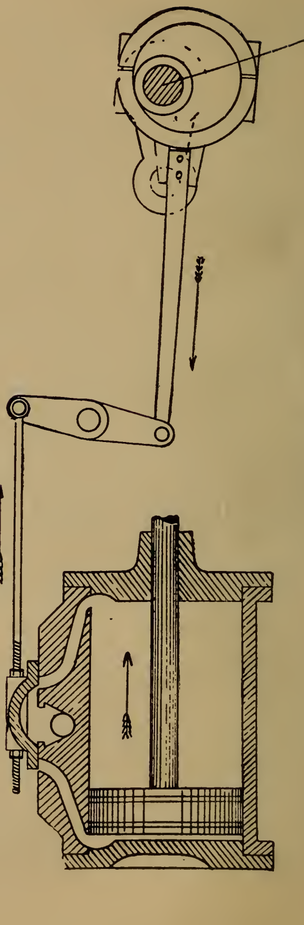


Fig. 18

caused by the eccentric-rod being too short and therefore the eccentric is unable to move the valve far enough to give full port opening.

Now, if the eccentric were to be turned to the opposite dead center or the center farthest from the cylinder we should find that the vaive would have moved too far, or, in other words, had moved more than enough to open the port wide. The whole movement or travel of the valve would be one-sided, and in the direction of the eccentric, and as this one-sided action is due to the eccentric-rod being too short the remedy lies in lengthening the rod. To do this we first place the eccentric in the position shown in Fig. 13, then proceed to lengthen the rod until the valve has moved to the position shown in Fig. 14, which represents the proper position of the valve when the eccentric occupies the position as shown, viz., having just opened the port wide. If however, when turning the eccentric to the position as shown in Fig. 13, we had found that the valve had more than opened the port, the eccentric-rod would then have been too long and the remedy would have been to shorten the rod until the position shown in Fig. 14 was obtained.

After having adjusted the eccentric-rod to the proper length we are ready to set the valve and we will assume the engine is to run "over," that is, if we were to stand at the opposite end of the engine from the crank, and facing the crank, should see the crank-pin rise as the piston moved away from the end of the cylinder at which we were standing the engine would then be running "over." When learning to set the valves in any engine, and in fact, in all engines, it is a good plan to have a common starting point, that is, no matter

what type of engine and valves are about to be set, always place the eccentric and crank on the same dead-center, and preferably the dead-center nearest the cylinder.

The advantage to be gained in having a common starting point and especially when learning to set valves, is that after the direction in which the engine is to run and the type of valve-gear employed are obtained all that is required is to

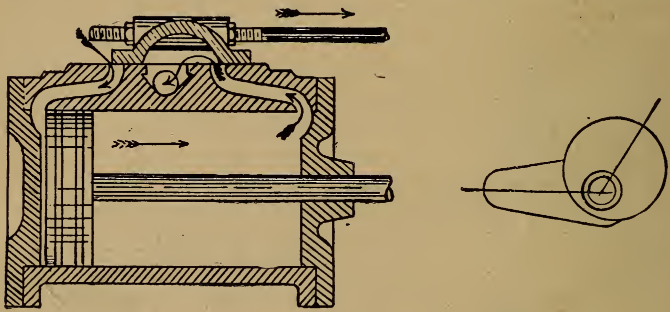


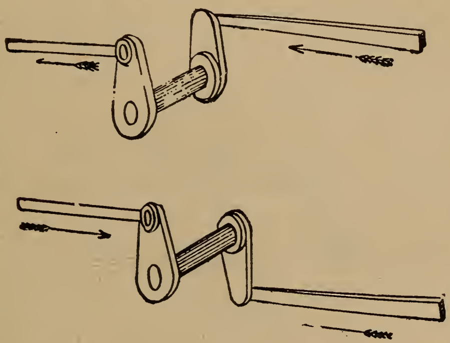
FIG. 15.

remember what direction of eccentric corresponds to the given type of valve-gear.

Fig. 15 represents the position of the valve, piston, crank and eccentric at the commencement of the stroke, which is to be in the direction indicated by the arrows.

Now, as the piston begins to move, more steam must be admitted to the cylinder, and by referring to the drawing it will be seen that in order to accomplish this the valve and the eccentric must move in the same direction as the piston; therefore in setting a slide-valve with plain gear we must

move the eccentric on the shaft (from the dead-center) in *the direction in which the engine is to run* until the valve opens the admission port to the amount of the lead which position is shown in Fig. 15. Never mind the position of the eccentric relative to the crank—that will take care of itself. All that is to be considered is the *direction* in which to move the eccentric and the position of the *valve* over the ports.. The set screws are now to be tightened, thus securing the



FIGS. 16 AND 17.

eccentric to the shaft. We do not *know* as yet whether the valve will open the opposite port to exactly the same amount as first obtained, therefore the engine is to be turned around to the opposite dead-center from that shown in Fig. 15 and the amount of lead determined.

Should a difference be found in the amount of lead from that first obtained, move the valve on the valve-stem to the amount of one-half the difference in the lead at either dead-

center, and which may be done by adjusting the jamb-nuts, nut or yoke as explained in a previous chapter.

It is better under ordinary circumstances to move the valve on the valve-stem or adjust the length of the stem for the purpose of equalizing the lead, than to change the length of the eccentric-rod after it has been properly adjusted. Having equalized the lead as described, the valve will be properly set.

The foregoing method of setting a slide-valve applies to engines equipped with a simple valve-gear; that is, without

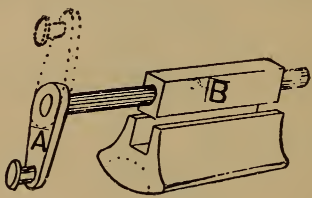


FIG. 19.

a rocker-shaft or other reversing mechanism placed between the eccentric and valve. It will be well to mention here that there is one form of rocker-shaft which will not change the foregoing method of setting a valve, and which is shown in Fig. 16. In this type of rocker-shaft the valve and eccentric both move in the same direction at the same time, so that as far as the influence of the rocker-shaft upon the movement of the valve is concerned it is equivalent to having the eccentric-rod connected directly with the valve-stem, hence no change is to be made in the foregoing method of setting a

valve when this type of rocker-shaft is employed. We will now consider a method of setting a slide-valve when a rocker-shaft as shown in Fig. 17 is employed, and which reverses the movement of the valve relative to that of the eccentric.

Referring to the drawing it will be seen that when the eccentric-rod moves in the direction of the arrow the valve moves in the opposite direction, which is also indicated by an arrow. This type of rocker-shaft forms what is known as a lever of the first class, viz., power is applied at one end (lower end), fulcrum in the middle and the weight, or resistance, at the other end (upper end). Before attempting to set the valve the eccentric-rod must be adjusted to proper length and in precisely the same manner as described in the case of a plain or simple valve-gear. The only change to be noticed is in the opening of the ports, for as the rocker-shaft reverses the direction of the valve relative to that taken by the eccentric-rod, the opposite port to that shown in Fig. 14 will be open when the eccentric occupies the position shown in the same figure. Bearing in mind the fact that the eccentric must move in the *opposite* direction to that in which the valve moves, we see by referring to Fig. 18 that as the piston begins to move in the direction of the arrow the valve must also move in the same direction, and that the eccentric must move in the *opposite* direction, and in order to do this it would have to be located somewhere in the vicinity of *o*, therefore, to find the exact location we turn the eccentric on the shaft in the *opposite direction* to that in which the engine is to run until the valve opens the port to the amount of the lead as shown in Fig. 18.

By again referring to the drawing it will be seen that when the eccentric moves toward the cylinder the *valve* moves toward the crank, or, in the direction in which the engine is to run, and thus corresponds to the movement of the valve as explained in the previous case, therefore the valve is set as far as the eccentric is concerned; all that remains is to equalize the lead, which is accomplished by turning the engine first to one dead-center and then the other, and measuring the amount of port opening or lead, which should be divided equally between the two ports by moving the valve on the stem, or, adjusting the length of the valve-stem as explained in the case of the simple valve-gear.

The Semi-Rotary or Rocker Valve.

The next to receive consideration is the semi-rotary or "rocker" valve so-called by some engineers, and which in reality is a plain "D"-valve working on a semi-circular valve-seat. The usual method of attaching semi-rotary valves to the valve-stem is shown in Fig. 19. The stem in this case extends at right angles to the direction in which the valve moves, the motion being imparted to the valve by means of the crank-arm *A*, attached to the outer end of the stem, and which in turn receives motion from the eccentric by means of the eccentric-rod. The oblong block *B*, is secured to the inner end of the valve-stem and fitted into the recess in the back of the valve, as shown immediately below it. This construction permits the valve to move in a vertical direction without springing the valve-stem the necessity for which was explained in connection with the plain slide-valve. The operation of a semi-rotary valve having the crank-arm *A*, in

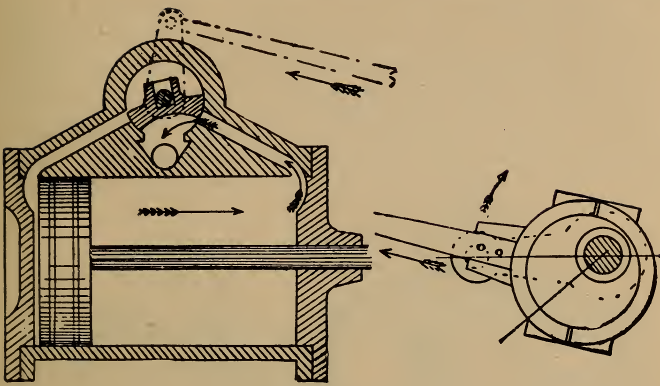


FIG. 20.

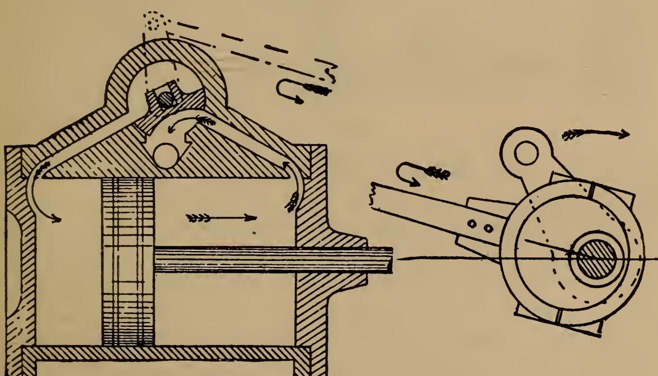


FIG. 21.

the position shown in Fig. 19 is identical with that of a slide-valve having a simple valve-gear, therefore further description will be unnecessary. Some engines are built with the valve placed below the cylinder and the arm *A* placed in the opposite position to that shown in Fig. 19. This arrangement changes the movement of the valve relative to that of the

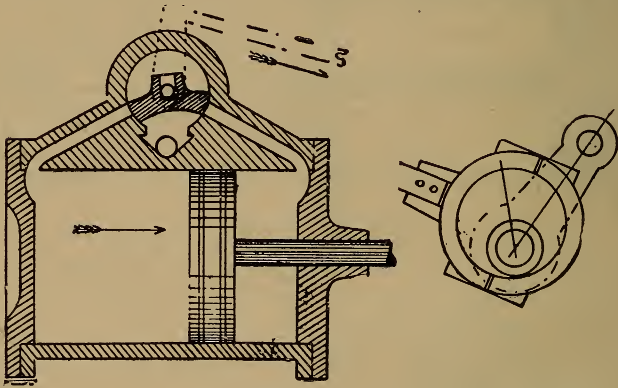


FIG. 22.

eccentric, having the same effect as the rock-shaft of the type shown in Fig. 17.

The operation of a semi-rotary valve fitted with the crank-arm in the position shown in Fig. 19 (dotted lines may be understood by referring to Fig. 20 which represents the cylinder inverted) shows the position of the valve, crank-arm, crank and eccentric at the commencement of the stroke which is to be in the direction of the arrow.

It will be noticed that the valve has opened the admission

port to the amount of the lead, and the center line of the eccentric is inclined away from a vertical position, which is due to the fact that the valve has lap, also that when the eccentric-rod moves in the direction indicated by the arrow the valve moves in the *opposite* direction.

Fig. 21 shows the position of the various members when the valve has completed its stroke and is ready to commence

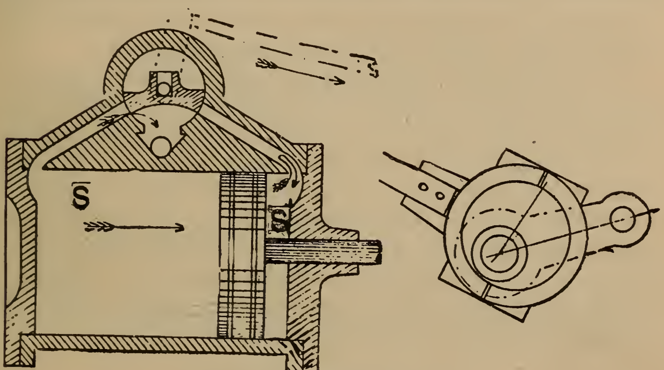


FIG. 23.

its return stroke, the piston having moved to about one-fourth stroke. Fig. 22 represents the valve as having returned on the backward stroke sufficiently to close the admission port and effect the "cut-off."

The difference between the positions shown in Figs. 22 and 23 represents the distance the piston has moved after cut-off has taken place or under expansion.

The left-hand edge of the exhaust cavity in the valve has

just commenced to open communication between the space *S* in the cylinder and the exhaust pipe, as indicated by the arrow, and, at the same time, the right-hand edge of the ex-exhaust cavity has just closed the port through which steam from the space S^1, in the cylinder has been exhausting, thus entrapping a portion of the exhaust steam in the cylinder, as indicated by the arrow; therefore the steam which has been thus shut in the cylinder is compressed by the piston into the clearance space during the remainder of the stroke.

The similarity in the action of a semi-rotary valve to a slide-valve may be readily comprehended by comparing the drawings in both cases, viz., those representing the positions of valve, piston, crank and eccentric in the case of the semi-rotary valve and those representing the same members in connection with the slide-valve. The method of setting a semi-rotary valve with the crank-arm in the position shown in Fig. 19 (dotted lines) is precisely the same as in the case of a plain slide-valve having a rocker-shaft placed between the eccentric and valve, of the type shown in Fig. 17.

The Riding Cut-Off.

The arrangement of valves in what is known among engineers as the "riding cut-off," comprises a ported main valve which lies next the cylinder (see Fig. 24) and an upper valve called the cut-off valve. The duty of the main valve is to admit steam to the cylinder, exhaust the same from the cylinder and produce compression. The duty of the cut-off valve is to shut off the supply of steam to the cylinder at the proper point in the stroke of the piston by closing the ports in the main valve. The back of the main valve forms the

valve seat for the cut-off valve, therefore the latter slides (or rides) on the upper side or back of the main valve, hence the term "riding cut-off."

In order to save confusion which might arise in attempting to carry the operations of both valves in mind at the same time we will consider them separately beginning with the main valve.

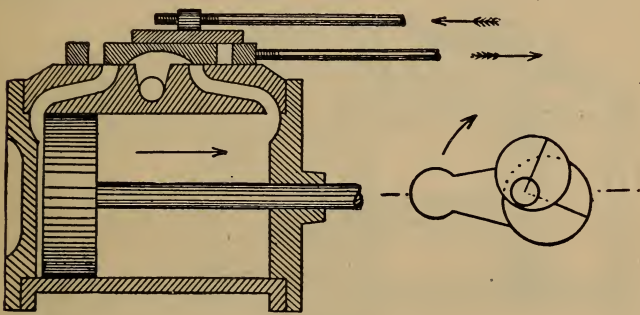


FIG. 24.

Fig. 24 represents the position of the main valve, piston, crank and main eccentric at the commencement of the stroke which is to be in the direction indicated by the arrow. The crank is now on the dead-center and the main valve has opened the admission port to the amount of the lead, the exhaust port at the opposite end of the cylinder being open to about one-fourth the width of the port. This is called exhaust lead, the object and advantages of which were described in a previous chapter. Fig. 25 shows the position of the piston,

crank and eccentric when the admission port is wide open, which occurs at about one-third stroke.

The main eccentric has now reached the dead-center farthest from the cylinder and the main valve has therefore completed its outward stroke and is ready to commence its return stroke, as indicated by the arrow.

Fig. 26 represents the position of the piston, crank and

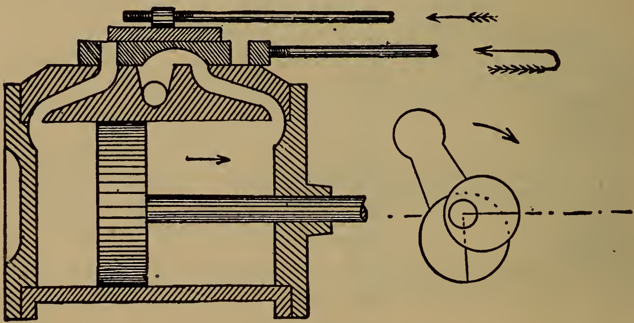


FIG. 25.

eccentric when the main valve has returned on its backward stroke a sufficient distance to just close the admission port producing "cut-off" which is at about three-fourths stroke. Fig. 27 represents the piston as having moved a little farther in the stroke and after cut-off occurred, or under expansion. The main valve has now just closed the exhaust port (at the right in Fig. 27), thereby producing compression. We also notice that the admission port is now open a very little, establishing communication between the space *S* in the cylinder

and the exhaust-pipe, or has opened the port to the amount of the exhaust lead (nearly).

The difference in the position of the piston in Figs. 26 and 27 indicates the distance the piston has moved under expansion, under the influence of the main valve only. From the foregoing it will be seen that the operation of a main valve in a riding cut-off is identical to that of a plain D valve having but little lap. The similarity may be made still more appar-

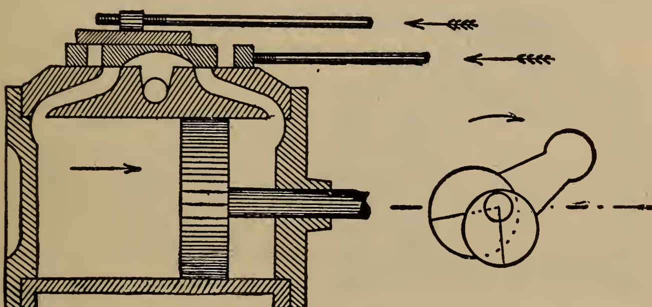


FIG. 26.

ent if the reader will compare the foregoing with the operation of a plain slide-valve with little lap as previously described.

We will now consider the effects produced by the addition of the riding cut-off valve. Fig. 24 represents as before the position of the piston, valves, crank and eccentrics at the commencement of the stroke. When the main valve occupies the position shown in Fig. 24 the cut-off valve has completed its outward stroke and has returned on its backward stroke to

the position shown. This may be more fully understood by referring to the position of the cut-off eccentric.

Fig. 25 shows the position of the cut-off valve when the main valve has opened the admission port in the cylinder to the fullest extent, and just about to close the port in the main valve and produce "cut-off," which now occurs at about one-third stroke instead of three-fourths stroke as when under the influence of the main valve only.

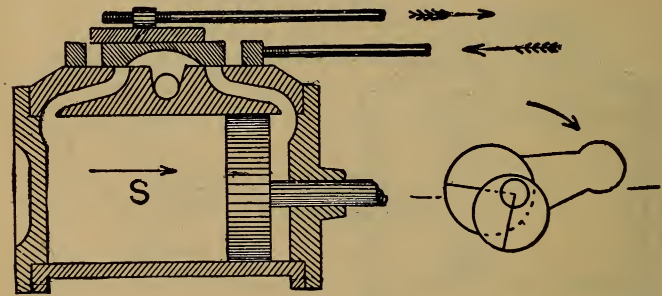


FIG. 27.

Now, by comparing Figs. 26 and 27, we may readily obtain the distance the piston moved under expansion when under the influence of the main valve only, and by comparing Figs. 25 and 27 we may obtain the distance (nearly) the piston moved under expansion when the cut-off was effected by means of the cut-off valve, and we see too that the earlier cut-off has been obtained without changing the main valve in any particular. Therefore while the point of cut-off has been changed from three-fourths stroke to one-third stroke, the

point of exhaust opening and the width to which exhaust-port has been opened and the point of compression all remain the same, and will remain the same for all points of cut-off unless the main eccentric is shifted on the shaft. In throttling engines the point of cut-off is changed (while the engine is running) by means of a hand-wheel or lever, placed at the end of the steam-chest farthest from the crank. By turning the hand-wheel in one direction the cut-off valve is lengthened and an earlier cut-off is the result, and turning the hand-wheel in the opposite direction, shortens the cut-off valve, producing a later cut-off.

This arrangement is called an adjustable cut-off and in this case both eccentrics are fixed to the engine shaft—the speed of the engine being regulated by the governor, which, as the name of the engine implies, *throttles* the steam and maintains a uniform rate of speed by varying the *pressure* of steam admitted to the steam-chest, to suit the load on the engine, the point of cut-off remaining as set by the hand-wheel or lever at the end of the steam-chest.

In the automatic cut-off engines the point of cut-off is automatically changed by the governor which is usually of the shaft type and which causes the cut-off eccentric to turn slightly on and around the shaft, advancing the position of the eccentric as the governor weights move outward, which in turn causes an earlier cut-off to take place, and again diminishing the advance of the eccentric as the speed of the engine decreases and the weights move toward the shaft. This in turn causes the cut-off to occur later in the stroke of the piston. This may be more fully understood by referring to Fig. 25. If the cut-off eccentric had been advanced to the

position represented by the dotted line, it would have reached the dead-center (now occupied by the main eccentric) earlier in the stroke of the piston, and consequently would have returned far enough on its backward stroke to close the admission port in the main valve when the piston occupied the position shown in Fig. 25.

On the other hand, if the governor had caused the cut-off eccentric to occupy a position corresponding to that of the main eccentric, the cut-off would have occurred when the piston had reached the position shown in Fig. 26. From this we see that, as the position of the cut-off eccentric is advanced relative to that of the crank, the cut-off occurs earlier in the stroke of the piston, and as the advance of the cut-off eccentric is diminished, the cut-off occurs later in the stroke. The principal advantages to be derived from the use of the riding cut-off over a single slide-valve are that it permits the point of cut-off to be changed, either by hand or automatically as the case may be without altering first, the amount of lead; second, the point of exhaust opening and the length of time the exhaust port is open; third, the point of exhaust closure, or the point of compression.

In slow and medium-speed engines it is an advantage to have the above operations occur at the same point in the stroke regardless of the point of cut-off, which cannot be accomplished with a single valve in an automatic cut-off engine as will soon be explained. We will now consider a method of setting a riding cut-off.

In setting the valves of a riding cut-off the main eccentric-rod must first receive attention and be adjusted to the proper length, which is done in precisely the same manner as in the

case of a plain slide-valve which has been fully explained in a previous chapter. It should have been stated that the cut-off valve is to be removed before attempting to adjust the length of the main eccentric-rod, otherwise the cut-off valve (in some types of gears) might obstruct the view of the main valve. After having adjusted the main eccentric-rod to the proper length, place the crank on the dead-center nearest the cylinder and also turn the full side of the main eccentric to a corresponding position. Next, determine the direction in which the engine is to run, then turn the eccentric on the shaft in the *same* direction, and until the port in the main valve opens the admission port in the cylinder to the amount of the lead. Now, if the engine is to run over and the eccentric has been properly set, the main valve will occupy the position shown in Fig. 24. Fix the eccentric to the shaft and turn the engine to the opposite dead-center, when the amount of lead should be the same as in the first position. If not, equalize in the same manner as for a plain slide-valve. Now place the cut-off valve on the back of the main valve and connect to the valve-stem. The length of the cut-off eccentric-rod must now be adjusted to the proper length, but before doing so, place the main valve (by turning the engine) in its position of mid-travel.

Turn the cut-off eccentric to the dead-center (either center) and measure the distance that the outer edge of the cut-off valve has moved beyond the inner edge of the port through the main valve, then turn the eccentric to the opposite center and again measure the distance as before. The distance referred to above must be equal when the eccentric occupies the above positions, viz., the dead-center.

In other words, the outer edges of the cut-off valve must move equal distances beyond the ports in the main valve, when the cut-off eccentric is placed on its dead-center. For the sake of simplicity we will assume that the engine has an adjustable cut-off and we wish the same to occur at one-half stroke. Place the crank on the dead-center nearest the cylinder and the full side of the cut-off eccentric the same. Now turn the engine in the direction in which it is to run, until the crosshead reaches exactly one-half stroke. Now turn the cut-off eccentric in the *same* direction until the cut-off valve opens the port in the main valve and again *just* closes it, but no more. Fix the eccentric to the shaft and turn the crank over the center and until the crosshead again reaches one-half stroke (this time on the return stroke) when the cut-off valve should have just closed the opposite port in the main valve. If it does, then the cut-off will occur at one-half stroke during the forward and backward stroke of the piston, but should there be a difference, then the cut-off eccentric must be moved slightly on the shaft until the cut-off is equalized; that is, until it occurs at the same point in both the forward and backward strokes. This done, the valves will be properly set for one-half cut-off.

It must be remembered by those not thoroughly familiar with the operation and setting of valves, it often happens that a valve will be badly "out," as engineers call it, when an engine is started up, after having the valve set as accurately as known methods will permit. The cause of this lies in the expansion of the cylinder, valve, valve-stem, etc., due to the heat of the steam, and should the valve be "out" sufficiently to cause the engine to run badly, the surest method of ascer-

taining the cause of the difficulty is in applying an indicator, which will show at a glance what expansion has done toward spoiling your work.

The Piston-Valve.

The piston-valve differs from the types of valves previously illustrated, and, when properly made and fitted to the valve-chest, it represents a cheap and durable form of

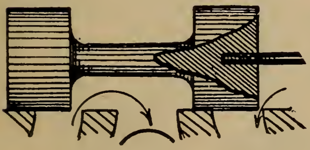


FIG. 28.

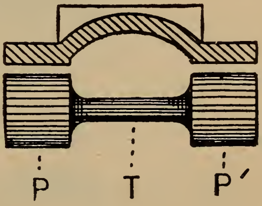


FIG. 29.

balanced valve. As will be seen by referring to Fig. 29 the piston-valve derives its name from its construction or form, being composed of two pistons *P* and *P′* connected together by the trunk *T*. The similarity that the piston-valve bears to the slide-valve in their relation to the steam-ports is shown in Figs. 28 and 29 which represent the two valves placed face to face, and also as having opened the steam-port to the amount of the "lead." In one type of piston-valve the trunk is made solid and when so made, steam is usually admitted to the cylinder at the ends of the valve as shown in Fig. 28. When this type of valve is employed the

operation of and the method of setting the valve are precisely the same as in the case of the plain slide-valve, therefore further description of this type of valve will be unnecessary. Another type of piston-valve, shown in Fig. 30, is the one most commonly employed. In this type the trunk is cast

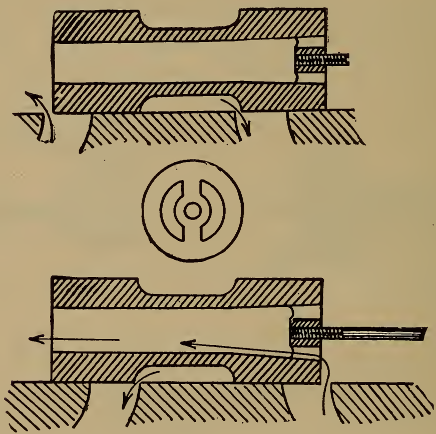


FIG. 30.

hollow, as shown, the valve-stem being screwed into the valve as indicated in Fig. 30.

In this valve the steam is admitted to the cylinder on the inside or between the pistons of the valve, the exhaust from one end of the cylinder passes through the hollow trunk to the exhaust-pipe and the exhaust from the opposite end ot the cylinder passes directly to the exhaust-pipe, as shown by

the arrows. This construction of valve permits exhaust steam only (and therefore steam of low pressure), to come in contact with and be held in by the joints between the valve-chest and the heads and also by the stuffing-box where the valve-stem enters the chest.

The operation of a piston-valve may be understood by referring to Fig. 31 which represents the position of the valve, piston, crank and eccentric at the commencement of the

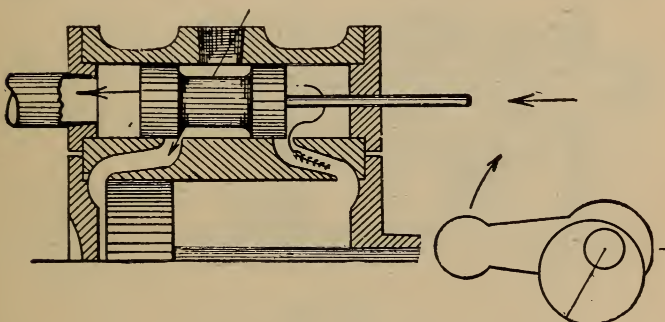


FIG. 31.

stroke which is to be in the direction of the arrow. The crank is now on the dead-center and the valve has opened the admission port to the amount of the lead. The opposite port is partly open to the exhaust, which opening you will remember, measures the amount of *exhaust lead.* Now, by referring to the crank and eccentric, it will be seen that as the former moves away from the dead-center in the direction of the arrow, the eccentric and therefore the valve, will move in the *opposite* direction, opening the port and so continuing

until arriving at the position shown in Fig. 32, which represents the port as wide open. The eccentric has now reached its dead-center nearest the cylinder and is therefore, ready to commence its return stroke and cause the valve to close the port—while the piston has moved to about one-third stroke. The cause of the valve moving in the opposite direction to that of the crank is that the valve admits steam from the *inside* instead of the *outside* as in the case of the plain slide-

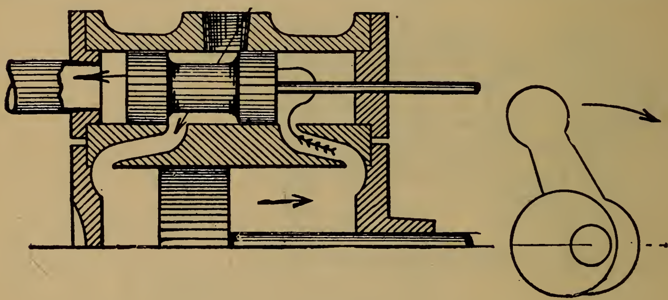


FIG. 32.

valve, (see Fig. 35) therefore, as the admission of steam takes place at the opposite end of the valve, so to speak, to that in the slide-valve, it is evident that the direction of the travel of the valve must also be in the opposite direction to that of the slide-valve when performing this function, if the engine is to run in the same direction in both cases.

Fig. 33 represents the position of the piston, crank and eccentric at the point of cut-off which is at about two-thirds stroke. The valve has completed its stroke in the direction indicated in Fig. 31, and has moved far enough on its out-

ward stroke to just close the admission-port. Fig. 34 represents the piston as having moved a little further in the stroke after the cut-off occurred or under expansion. The valve is now beginning to open the admission-port to the exhaust and at the same time has just closed the port (at the right in the drawing) through which steam has been exhausting during the forward stroke of the piston, thus producing compression. The difference in the position of the piston in

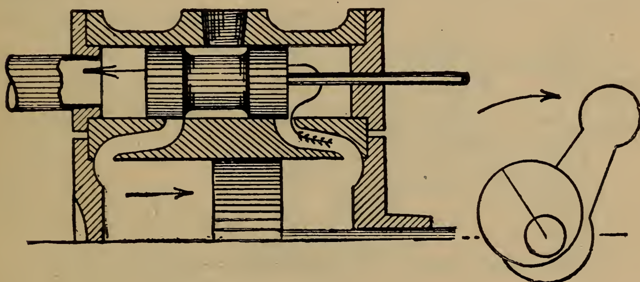


FIG. 33.

Figs. 33 and 34, represents the distance the piston moved under expansion.

Having now a fair understanding of the operation and the position of the valve relative to that of the piston at various points in the stroke, we will consider a method of setting a piston-valve of the type just explained. First, place the eccentric on the dead-center next to the cylinder and with hammer and prick-punch make a punch mark on the valve-stem near the valve-stem guide and a similar mark on the guide itself and with a pair of compasses take the distance

between the two punch marks. The object in making punch marks upon the valve-stem before commencing operations is for the purpose of enabling the engineer to return the several parts to their original position should occasion demand it, and a fresh start made, which would be found difficult to accomplish when the edges of the valve and steam ports cannot be easily seen as in the case of the piston-valve. It may be well to remark here that it is a good plan to mark the various parts of any machine before attempting to take it apart and

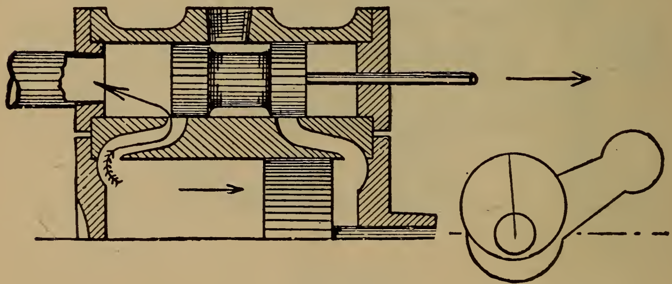


FIG. 34.

especially so when one is not sufficiently familiar with the mechanism in hand to know the exact position each part should occupy and the relation of each part to the others.

We are now ready to disconnect the valve-stem from the guide-block. This done, take off the back chest-cover and pull out the valve and stem, then take off the other chest-cover. Next make a template of thin sheet iron or steel about an inch wide and make the length of the template equal to the thickness of one of the pistons of the valve *plus the lead*, as shown in Fig. 36. With a scriber in one

hand place one end of the template against the inner side of the port and with the scriber make a fine mark or line at the other end of the template as shown in Fig. 37. Repeat the operation at the opposite end of the chest. Now place the valve in the chest and slip the inner chest-cover on the valve-stem and connect the latter to the guide block, bringing the punch marks to their original position with the compasses.

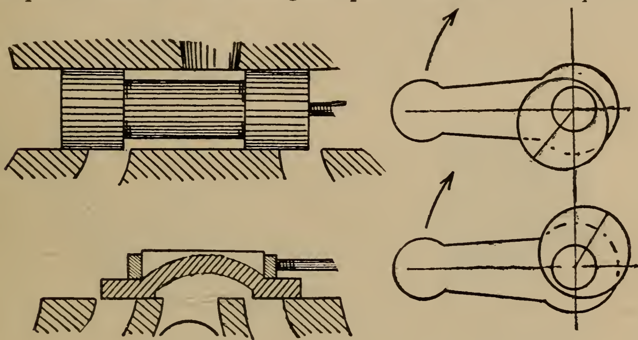


FIG. 35.

Before attempting to set the valve, we must first adjust the length of the eccentric-rod to the proper length, which is accomplished by turning the eccentric first to one dead-center and then the other, seeing that the *outer* edges of the valve open the ports to an equal amount when the eccentric occupies these positions. In observing the operation of the piston-valve in the foregoing explanation, we found that the direction of the valve travel was *opposite* to that of the piston when the latter was at or near the dead-centers, therefore, after placing the crank on the dead-center nearest the cylinder,

turn the eccentric on the shaft in the *opposite* direction to that in which the engine is to run, until the *outer* edge or *end* of the valve just coincides with the fine line drawn on the valve-seat farthest from the crank. The *inner* edge of *that* piston of the valve will then have opened the steam port to the amount of the lead. Fix the eccentric to the shaft and turn the crank to the opposite dead-center when the outer

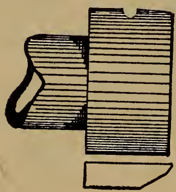


FIG. 36.

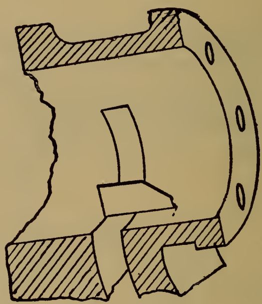


FIG. 37.

edge of the valve (at the opposite end of the chest) should coincide with the line drawn on the valve seat.

If it does, then the *inner* edge of that piston of the valve also opens the steam port to the amount of the lead. Replace the chest covers and the job is finished, but whether it will remain "finished" or not when the engine is started up under steam is another question and one difficult to answer until the engineer's friend, the indicator, is called upon for a card which is equivalent to a mirror, reflecting the work of the valve with ideal clearness and accuracy.

The Centrifugal Shaft-Governor.

How it Effects the Distribution of Steam.

Owing to the multitude of designs of automatic shaft-governors now in use, many of which are, in operation, exactly alike, differing only in minor detail—the same general principle being embodied in each—it becomes impracticable to attempt to describe all forms of shaft-governors, therefore we will confine ourselves to the principle of the shaft-governor upon which the majority of governors are designed.

In the first place let us consider the practical operation of the movable eccentric used in connection with the shaft-governor. Some engineers claim that the "throw" of an eccentric is equal to the *eccentricity* of the eccentric while others (probably the majority) claim that the throw is equal to the distance the eccentric is capable of moving the valve, without multiplying mechanism interposed between the eccentric and valve. As the latter definition is usually accepted among engineers as the more nearly correct we will here consider the "throw" of an eccentric as being equal to the distance the latter is capable of moving the valve, or as being equal to the valve-travel. The diameter of an eccentric usually suggests the extent of the "throw," namely, when we hear of an eccentric two feet in diameter, it immediately suggests a very long valve-travel, and when we hear of a 100-h. p. engine having eccentrics of four or five inches in diameter, it usually suggests a short valve-travel, and, while these inferences may prove to be correct in many instances, yet the diameter of an eccentric really has nothing to do with

its throw or the distance it is capable of moving the valve, that is, within certain limits.

This may be understood by referring to Fig. 38 which

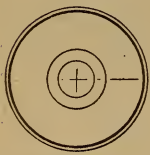


Fig. 38

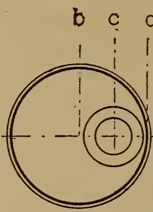


Fig. 39

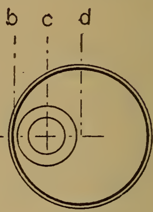


Fig. 40

Fig. 41

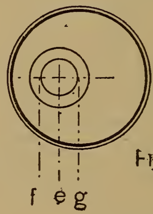


Fig. 42

Fig 43

represents an eccentric-disc or "block" as it is often called. in which the eccentricity is zero.

Now, in this case, it would make no difference whether the diameter was ten feet or ten inches, the *throw* will still

be zero. From this we see that the throw of an eccentric is dependent upon the amount of eccentricity given it, which is measured by the distance between the center of the eccentric and the center of the shaft. Referring to Fig. 39 we find an eccentric-block of the same diameter as in Fig. 38, but the eccentricity is now apparent and is measured by the distance between the points *b* and *c*, and if the eccentric should be turned to the position shown in Fig. 40, or one-half revolution, it would have moved the valve a distance equal to *b d*, which is twice the distance of *b c*, therefore the throw of an eccentric as we are considering it, is equal to *twice* its eccentricity, or twice the distance between the center of the eccentric and the center of the shaft. In Fig. 41 the diameter of the eccentric is the same as before, and the eccentricity is measured between the points *e f*, which is about one-half the distance of *b c* in Fig. 39.

Now, if this eccentric should be turned to the position shown in Fig. 42 or one-half revolution, the eccentric would have caused the valve to move a distance equal to *f g*, or twice its eccentricity, but the valve would have moved but one-half as far as in Fig. 40. The eccentricity of the eccentric in Fig. 41 has been diminished, that is, the distance between the center of the eccentric and the center of the shaft has been lessened, therefore we see that the throw of an eccentric depends upon the distance between the center of the eccentric and the center of the shaft and that when this distance is diminished the travel of the valve is shortened. The duty of the governor-weights and their connecting levers is to diminish the eccentricity of the eccentric and this is accomplished by moving the eccentric across the shaft. Fig.

43 represents the position of an eccentric at the commencement of the stroke of the piston. It is represented as having "angular advance," which has caused the valve to move from its position of mid-travel to that shown. The valve has now opened the admission port to the amount of the lead. Fig. 44 represents the eccentric as having been moved a certain

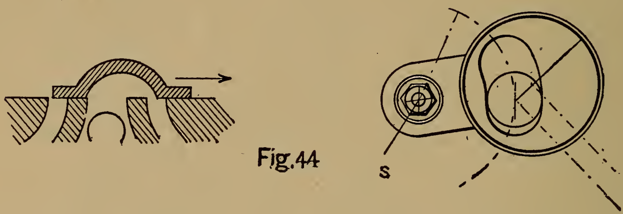


Fig. 44

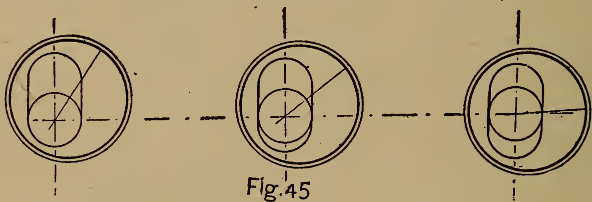


Fig. 45

distance across the shaft, and it will be noticed that the distance between the center of the eccentric and the center of the shaft has been diminished to about three-fourths of that shown in Fig. 43 and the travel of the valve will also be three-fourths of that in Fig. 43. The foregoing illustrates the principle involved in the operation of a shaft-governor and shows the manner in which the governor-weights effect the valve-travel. It will now be noticed that the center

line of the eccentric inclines further to the right in Fig. 44 than in Fig. 43, showing that diminishing the eccentricity of the eccentric (and therefore the valve-travel) has had the effect of increasing the "angular advance," for turning to the valve in Fig. 44, we find the lead greater than in Fig. 43. This illustrates the fact that in this form of governor (which represents in principle a very large number of those in use) when the distance between the center of the eccentric and the center of the shaft is *diminished* the *lead* is *increased*, and in many instances this proves to be an advantage, while in others it is very doubtful if any material benefit arises therefrom.

The cause of this increase in lead is due to the fact that the center of the eccentric when moved across the shaft describes an arc of a circle the center of which is at *s*. Until within a comparatively short time, the above result was obtained in all shaft-governors, viz., the lead increased as the travel of the valve was shortened, but today there are several forms of shaft-governors so constructed that the lead remains constant for all positions of the eccentric, and consequently for all lengths of valve-travel within the limits of the governor.

One of the most common methods of obtaining constant lead for various lengths of valve-travel is illustrated in Fig. 45.

In this type of governor the eccentric is moved straight across the shaft as indicated instead of describing an arc of a circle as previously mentioned. Fig. 45 shows the position of the eccentric when in "full gear," or the position corresponding to latest cut-off—earliest cut-off and an intermediate position being shown in the central figure.

We are now prepared to consider the *effect* upon the

points of cut-off, release (or exhaust) and compression, and

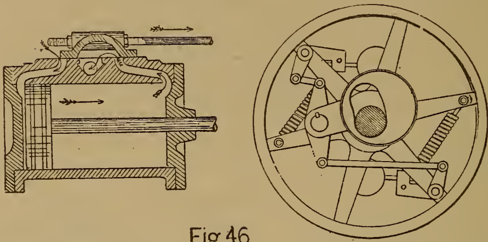


Fig. 46

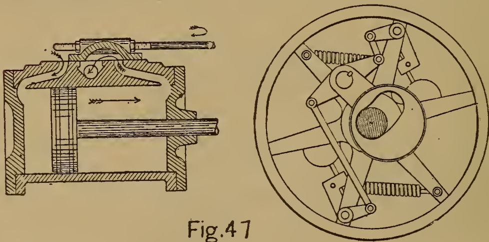


Fig. 47

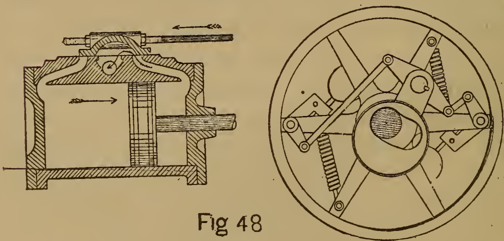


Fig 48

also upon the period of expansion, due to shortening the valve-travel. We will first consider the above points of cut-

off, release, etc., in an engine, say when starting and before the speed has increased sufficiently to cause the governor-

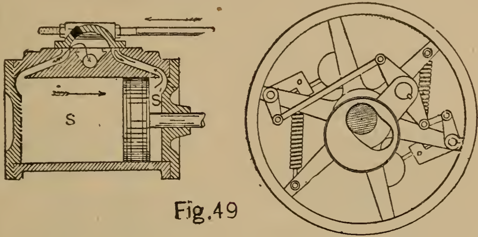


Fig. 49

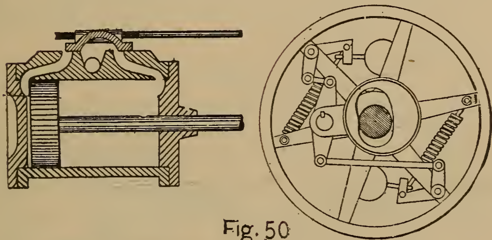


Fig. 50

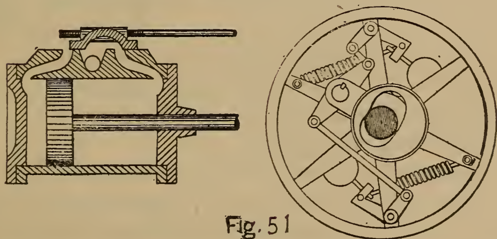


Fig. 51

weights to move outward, or before the governor has effected the length of the valve-travel. Fig. 46 represents the position

of the piston, valve, and eccentric at the commencement of the stroke.

The valve has now opened the admission port to the amount of the lead, the opposite port is open a little to the exhaust, which opening measures the amount of exhaust lead.

Fig. 47 represents the admission port as wide-open, the eccentric having reached the dead-center farthest from the cylinder, while the piston has moved to about one-third stroke. Fig. 48 shows the relative position of the piston, crank and eccentric at the point of cut-off, which occurs at about two-thirds stroke. Fig. 49 represents the piston as having moved a little further in the stroke after cut-off occurred, or under expansion.

The valve has now just closed the exhaust (at right in drawing), thus producing compression which occurs at about nine-tenths stroke. The admission port (at left in drawing) is now open a very little to the exhaust, the piston in its present position marking the point of release also. Let us now consider the effect of reducing the valve-travel which is accomplished by the governor in the manner previously described. Fig. 50 represents the position of the piston, valve and eccentric at the beginning of the stroke.

The valve has now opened the admission port to the amount of the lead which is greater than in Fig. 46 as is also the amount of exhaust lead.

Fig. 51 represents the position of the piston, valve and eccentric when the admission port is wide open, or as far as can be opened with the present reduced valve-travel, the eccentric having reached the dead-center farthest from the cylinder as before, while the piston has moved to about one-fourth stroke.

Fig. 52 represents the position of the foregoing members at the point of cut-off which now occurs at one-half stroke instead of two-thirds stroke as in the preceding case. Fig. 53 shows the piston as having moved further in the stroke, and after the cut-off occurred, or under expansion.

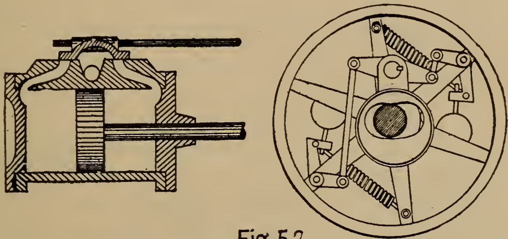


Fig. 52

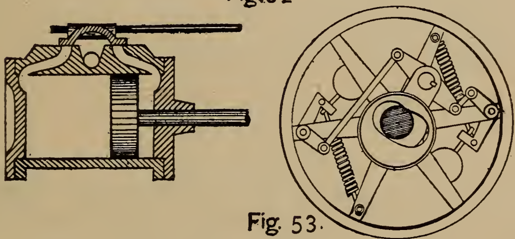


Fig. 53.

The period of expansion is now greater than in Figs. 48 and 49. The valve has now closed the exhaust port (at right in drawing) producing compression, which now occurs at seven-eighths stroke instead of nine-tenths stroke as in Fig. 49. The present position of the piston (Fig. 53) also marks the point of release which occurs earlier on the return stroke than in the preceding illustration.

Finally, the shaft-governor changes the point of cut-off by shortening the travel of the valve, and this, by lessening the distance between the center of the eccentric and the center of the shaft which is accomplished by moving the eccentric across the shaft.

The *effect* of shortening the travel of the valve is: First, in increasing the lead, both steam and exhaust; second, in diminishing the port opening for the admission of steam to the cylinder; third, in producing an earlier cut-off, thus increasing the period of expansion; fourth, in causing the point of release to occur earlier in the forward stroke and also a reduction in the port opening for the exhaust steam to escape from the cylinder; and lastly, in causing the point of compression to occur earlier on the return stroke, thus entrapping a larger volume of exhaust steam in the cylinder which increases the pressure of compression.

Setting a Link-Motion.

The types of valve-gears which have been illustrated, comprise those generally used on stationary engines. The link-motion, however, is used principally on locomotive, marine and hoisting engines, and also on some makes of portable (traction) engines.

The movable-link or link-motion is, in itself, a very simple mechanism, and in operation it is equally simple and presents one of the best forms of adjustable valve-gear as well as reversing gear. Those who have been successful in comprehending the operation of a slide-valve actuated by a single eccentric as illustrated in previous chapters will readily

understand the operation of the link-motion by referring to Figs. 54, 55, 56, 57, which represent the relative positions of the various members of which a link-motion is comprised.

Notwithstanding the simplicity of the link-gear in construction, as well as operation, the problems met with in designing a link-gear and the points to be considered when setting the same are, respectively, as difficult and as many as in almost any other form of valve-gear.

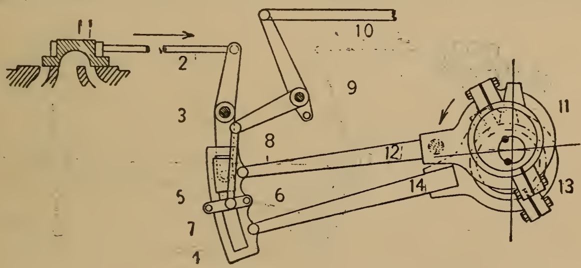


FIG. 54.

Engineers are seldom, if ever, called upon to design a link-gear; therefore, we will turn our attention to the work of setting the same, as this information is of much importance to men in the shop as well as the engine-room.

But, before we begin the work of setting the eccentrics, it may be to the interest of some of us to obtain the names of the various members of a link-motion. Fig. 54 represents this form of valve-gear as applied to locomotive, hoisting and portable engines (in marine gears the rocker-shaft is usually dispensed with), in which 1 is the valve, 2 the valve-stem, 3

the rocker-shaft, 4 the link, 5 the link-block, 6 the saddle, 7 the saddle-pin (or hanger stud), 8 the link-hanger, 9 the tumbling-shaft, 10 the reach-rod, 11 the forward eccentric with strap, 12 the forward eccentric-rod, 13 the backing (or back) eccentric with strap, 14 the back eccentric-rod.

The terms "forward" and "backward" and forward eccentric and backing eccentric, when applied to the gear of a stationary engine do not convey a very definite idea of the direction in which the engine will run when corresponding to

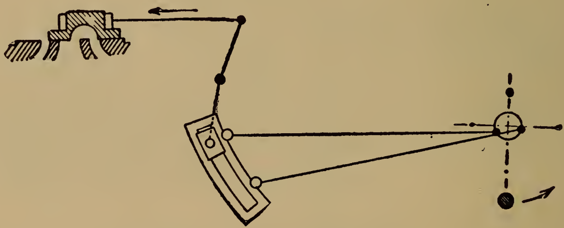


FIG. 55.

either eccentric. It depends largely upon the direction required in the machinery being driven as to which will be respectively the forward and backing eccentric. Engineers, however, when setting a link-gear usually consider the engine aside from the machinery being driven, and when so considered, the direction corresponding to forward and backward, respectively, is the same as in the locomotive, namely—when the engine runs "under" it is said to be running forward or ahead, and when running "over" it is said to be running backward or backing. The meaning of the terms "over" and

"under" were described in a previous chapter, together with a rule for ascertaining the direction in which any engine runs. In marine engine practice the terms employed to designate the direction in which the engine runs, are "ahead" and "astern." The eccentric actuating the valve when the vessel moves ahead is called the forward eccentric and the eccentric actuating the valve when the vessel moves backward or astern is called the backing eccentric. In the locomotive of the present design the forward eccentric-rod is attached to

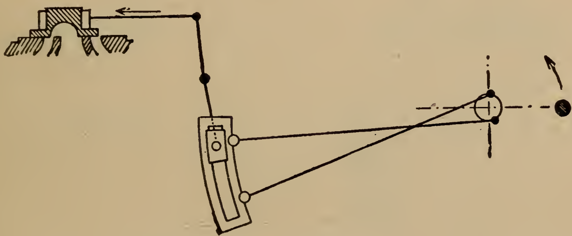


FIG. 56.

the upper end of the link, and the rod of the backing eccentric is attached to the lower end of the link, therefore, in stationary engine practice, it is customary to connect the rod of the eccentric which causes the engine to run "under" to the upper end of the link and the rod of the eccentric causing the engine to run "over" to the lower end of the link. This applies to gears in which a rocker-shaft is employed of the type shown in the drawings. A link-gear without rocker-shaft will be considered later.

With the foregoing points well established in our minds

we shall find the work of setting a link-motion much more simple than some engineers would have us suppose.

Before attempting to set the eccentrics we will first set the upper arm of the rocker in a vertical position—plumb. The valve should now occupy the position of mid-travel; that is, the outer edges of the valve should extend an equal distance beyond the outer edges of the steam-ports. This position may be readily obtained by measuring the length of the valve and from this distance subtract the distance between

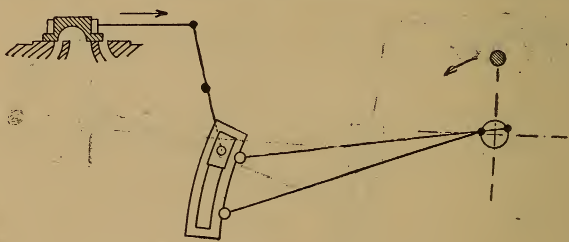


FIG. 57.

the outer edges of the steam-ports. Divide the remainder by two and lay off the quotient from the outer edge of the steam-port. When the upper arm of the rocker is plumb, the edge of the valve should coincide with this line. This operation gives us the proper length of the valve-stem. Place the reversing lever in position of full forward gear. In the method of setting a link-motion which follows, the same starting point is observed as in all previous cases, namely; the crank and the full side of both eccentrics are turned to the dead-center nearest the cylinder. When occupying this

position the valve, rocker-shaft and the *centers* of the eccentrics (which are represented by round dots) will be in the position shown in Fig. 58.

We will first set the forward eccentric.

It will be remembered that, when an engine runs *forward* it runs "under," which is in the direction of the arrow, see Fig. 58, and the rocker-shaft is of the type that reverses the motion or direction of the valve relative to that of the eccentric, therefore we turn the eccentric in the *opposite* direction

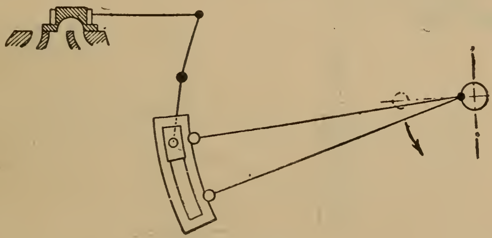


FIG. 58.

to that corresponding to "forward" until the valve leaves the steam-port open to the amount of the lead, when the various members will occupy the position shown in Fig. 59.

Tighten the set-screws in this eccentric.

Now, throw the reversing lever into the position of full backward gear. This operation will raise the link and bring the rod of the backing eccentric in line with the link-block and the valve will then occupy the same position as in Fig. 58.

When an engine runs backward, it runs "over" and ob-

serving the same rule as before, we turn the backward eccentric "under" until the valve leaves the *same* steam-port open to the amount of the lead.

Throw the reversing lever into the position of full forward gear again, when the valve will occupy the position shown in Fig. 60; also the eccentric centers. In a link-gear which has been properly designed and well adjusted, the valve should occupy the same position over the ports, whether the link is

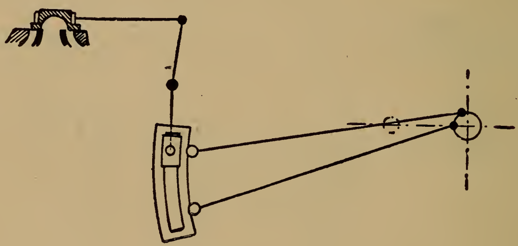


FIG. 59.

in full forward or full backward position—the crank being on the dead-center.

Now turn the crank to the back dead-center and measure the amount of the lead which will seldom be the same as it was when the crank occupied the forward center. Sometimes the lead will be greater when on the back center, and at other times there will be no lead at all, the valve being what engineers call "blind."

We will assume that the lead has been measured with the crank on both the forward and back centers. When on the

forward center it was three-thirty-seconds of an inch, and when on the back center the valve was blind. This indicates that the forward eccentric-rod is too long and must be shortened an amount equal to one-half the difference in the lead as obtained on both centers, which would be three-sixty-fourths of an inch.

Put the reversing lever in position of full backward gear, engine still on back-center and measure the lead, then turn to the forward center and again measure the lead. If in the latter position it is found to be too great, it indicates that the backing eccentric-rod is too long and must be shortened an amount equal to one-half the difference in the lead when the crank occupies either center.

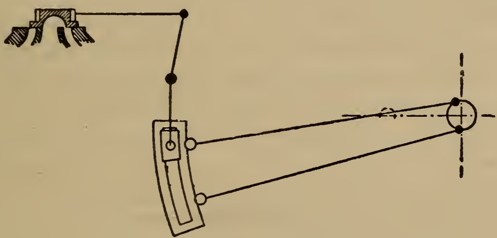


FIG. 60.

The work of equalizing the lead may necessitate turning the engine from one center to the other several times in both forward and backward gear, but when the equalization is accomplished, the link-motion will have been correctly set as far as the lead is concerned.

In the foregoing directions, the proper place for the revers-

ing lever when beginning the work of setting the eccentrics was given as full forward and full backward gear respectively.

Upon this point in setting a link-gear engineers do not agree. Some prefer to place the reversing lever in the position it usually occupies when the engine is running and set the eccentrics with the reversing lever in this position. Others select the full gear position which is undoubtedly to be preferred when the link is used for reversing the direction of the engine only, the *speed* being governed by a governor. When setting a link-gear, however, the method to be adopted should be governed by the running qualities produced, that is to say, if an engine runs smoother when "hooked back" (the eccentrics having been set in full gear) then the valve should be re-set with the reversing lever in the running position and vice versa.

Forward Gear.

Am't of Lead	Forward Center.	Am't of Lead	Back Center.
Too Much.	Shorten forward rod.	Too Much.	Lengthen forward rod.
Not Enough.	Lengthen forward rod.	Not Enough.	Shorten forward rod.

Backward Gear.

Am't of Lead	Forward Center.	Am't of Lead	Back Center.
Too Much.	Shorten backing rod.	Too Much.	Lengthen backing rod.
Not Enough.	Lengthen backing rod.	Not Enough.	Shorten backing rod.

The accompanying table contains in condensed form, the foregoing directions for adjusting the length of the eccentric-rods when equalizing the lead, and may be readily comprehended by referring to the drawings. The *amount* either rod is to be lengthened or shortened is given in the preceding lines.

Having set the eccentrics and equalized the amount of lead, the same operations must be repeated at the opposite side of the engine, assuming that it is a double engine with cranks set at right angles or at 90 degrees as in the locomotive and most types of hoisting engines. In small engines the work of setting the valves usually ends with equalizing the lead, but in engines with cylinders of the size of those in locomotives or larger, we must go a step farther and equalize the cut-off for it is important that about the same amount of steam should be admitted to each cylinder and to each end of the cylinders. The angularity of the connecting-rod tends to give a greater supply of steam to the forward end of the cylinder, and in a new and well-designed gear, this inequality is usually very nearly corrected when designing the gear by locating the hanger-stud a very little back of the center of the link (see Fig. 54). Before we begin operations it might be well to state that when the link-gear is used for reversing only, the reverse-lever is usually placed in full gear forward and back when setting and adjusting the valves, but when the engine is usually run with the link hooked up, place the reversing lever in that notch, forward and back, in which it is usually kept when the engine is running. For the purpose of illustration and simplicity we will assume that the link is used for reversing only. First place the reverse-lever in position of full forward gear and turn

the crank to the exact dead-center nearest the cylinder. The valve will now have opened the port at the head-end of the cylinder to the amount of the lead. Now have the engine turned forward (" under") slowly.

The valve will be seen to open the port until the cross-head reaches nearly one-half stroke, when it will begin to return and close the port again and until cut-off is reached. At this point the engine must be stopped. Measure on the guide the distance the cross-head has moved from the end of the stroke and make note of it. Then have the engine turned in the *same* direction and obtain the cut-off for the forward stroke in the same manner and make note of this also. Find the points of cut-off in the other cylinder in precisely the same manner.

Suppose one engine to be 10 inches by 20 inches and that on the forward stroke on one side the valve admits steam to say 16 inches and on the opposite side to 17 inches of the stroke. This inequality may be corrected by lengthening one link-hanger and shortening the other; in other words, the hanger on the side cutting off at 16 inches must be lengthened, and the one on the side cutting off at 17 inches must be shortened. If the discrepancy is less than that given in this size of engine the short side only may be lengthened. The amount of adjustment to be given the hangers can only be had by trial. As link-hangers are seldom provided with means for adjusting their length, it will be found more convenient to move the arms on the tumbling-shaft. When both arms are to be moved on the tumbling-shaft, it is better to mark the position of the link on the short side. Lengthen or lower this side the whole amount necessary, then raise it to one-half this

amount and raise the opposite link an amount equal to one-half the whole distance required in the first link. Equalizing the cut-off for both strokes in the same cylinder is a harder undertaking.

In new work, as stated, this inequality may be overcome by the saddle stud but in merely resetting this will not be admissible.

Supposing that in our cylinder the cut-off occurs at 15 inches on the backward stroke and at 16 inches on the forward stroke, we must first endeavor to locate the cause of the trouble.

Examine the rocker-arms to ascertain whether they are not sprung. If all right, examine the link which may be sprung out of its true radius.

In all cases ascertain the condition of the joints that the difficulty may not be due to lost motion.

Where it is impracticable to remedy the discrepancy by correcting the origin of the trouble it may be accomplished in other ways. If the inequality is very slight it may be remedied by throwing out the back motion or by lengthening or shortening the valve-stem when the valve is in the position of mid-travel. It very often happens that the equality of lead opening must be sacrificed to obtain equality of cut-off.

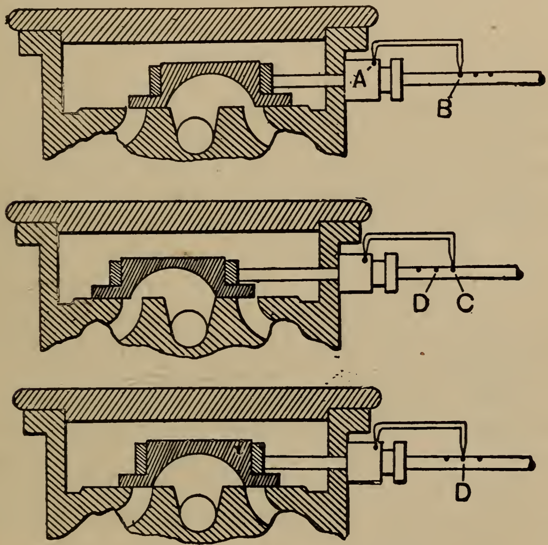
It may be well to state that with a distorted link-motion the changes necessary to obtain a correct adjustment of the various members cannot be expected the first time trying by one who has had little or no experience in such work. Even with experienced men it is often a case of "try, try again." In the link-motion, and in fact in valve-gears of any kind having as many unadjustable working joints as the link-

gear, considerable trouble is often experienced from lost motion when endeavoring to equalize the movements of the valve. These difficulties however may be very easily remedied as follows: When moving an eccentric from the dead-center to the required position, move it a little beyond and then back to the correct position. When equalizing the lead and cut-off it is necessary that the lost motion be taken up, and this may be done by allowing the crank-pin to move a little beyond the center and then back to the exact dead-center.

It sometimes happens that an engineer is required to reset a valve during working hours owing to an eccentric slipping on the shaft or other reasons; therefore, it is a good plan to have an emergency method of setting the valves and without removing the steam-chest cover. We will assume now that the eccentrics have been set and the final adjustments made with the steam-chest cover off as given in the foregoing lines. Before replacing the steam-chest cover, place the reverse-lever in full forward gear and turn the crank to the dead-center nearest the cylinder, taking up the lost motion in the manner explained. With hammer and prick-punch make a punch mark on the stuffing-box (not the gland) as at *A*, Fig. 61.

Now, before moving the engine procure a piece of steel wire, say three-sixteenths or one-fourth of an inch in diameter, and long enough to make a tram of the form shown in Fig. 61. Grind the ends to a sharp point and bend them down as shown making one leg a little longer than the other. After making the tram place one leg in the punch mark at *A* and with the other make a fine line on the valve-stem.

On this line make another punch mark as shown at *B*. Turn the engine ahead (under) until the crank reaches the back center, and after taking up the lost motion as before, again place the short leg of the tram in the punch mark on



FIGS. 61, 62 AND 63.

the stuffing-box and with the long end make a fine line on the valve-stem as before and on this line put a punch mark as at *C*, Fig. 62. Now divide the distance between the punch marks *B* and *C* and in the center place a third punch mark as at *D*.

The mark *D* is to be used when we wish to place the valve in the position of mid-travel as shown in Fig. 63, which position becomes necessary when adjusting the length of the valve-stem.

To set the valve by means of the punch marks the engine is first placed on the center nearest the cylinder and the full side of the eccentric to be set, the same. Place the reverse-lever in position of full forward gear (if the forward eccentric is to be set or full back gear if the back eccentric is to be set) and with tram in hand, have the slipped eccentric turned in the proper direction until the punch mark *B* (punch mark *C* for back gear) reaches the long leg of the tram as shown in Figs. 61 and 62 respectively. Have the eccentric fixed at this point and the engine will be ready to start. These punch marks may be used for the purpose of equalizing the cut-off also, by first placing the crank in the same position as for setting the eccentrics, then have the engines turned ahead when the mark *B* on the valve-stem will be seen to move away from the tram until the cross-head has reached nearly one-half stroke, when it will return to the point of the tram, as in Fig. 61. This marks the point of cut-off and the distance the cross-head has moved away from the end of the stroke represents the distance that steam is admitted to the cylinder before cut-off occurs.

The same operation is repeated for the forward stroke starting from the back center and using the punch mark *C*. Then place the reverse-lever in position of back gear and proceed in precisely the same manner, to find the point of cut-off when the engine is backing.

There are certain peculiarities observed in the operation

of a link-motion and certain terms used in connection therewith, an explanation of which may not be without interest.

The first is the crossing of the eccentric-rods when the crank occupies the back center.

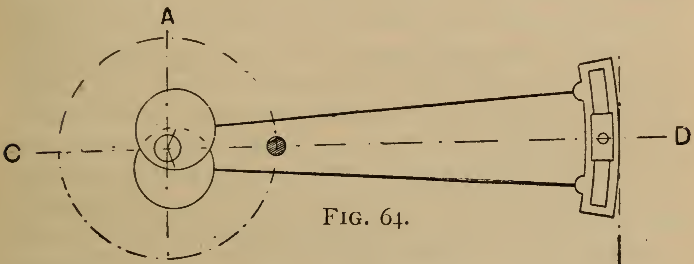


FIG. 64.

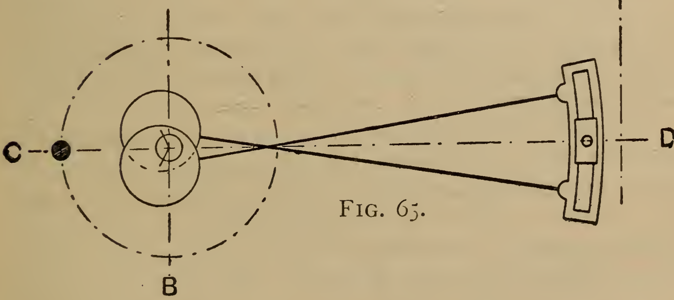


FIG. 65.

This position of the rods may be readily understood by referring to the *centers* of the eccentrics which are located at the extremities of the heavy lines indicating the position of the full part of the eccentric. In Fig. 64 the centers of both eccentrics are between the centers of the shaft and the link,

the center of the forward eccentric is above and that of the back eccentric is below the center of the shaft.

The rod from the forward eccentric is attached to the upper end of the link, and the rod from the back eccentric is attached to the lower end of the link. Fig. 65 represents the crank (and shaft) as having made one-half revolution and the centers of the eccentrics are on the opposite side of the center of the shaft from the link, the center of the back eccentric is now above the center of the shaft and that of the forward eccentric is below the center of the shaft, and, as the outer ends of the eccentric-rods are attached to the same ends of the link as in Fig. 64, it is evident that they must be crossed when the crank occupies the back center.

It is well known among engineers that the lead of a valve operated by a link-gear increases as the link is "hooked up," that is, as the link is raised and the link-block approaches the center of the link as in Fig. 64. This position of the link is known as mid-gear.

The cause of the increase in lead as the link approaches mid-gear may be understood by first referring to Fig. 64, which represents the relative position of the link and eccentrics when the crank is on the forward center. The centers of the eccentrics are a certain distance ahead of the center of the shaft, or line *A B*. When the link is moved up or down, each eccentric-rod pin (in the link) describes an arc of a circle, the radius of this arc being equal to the distance between the centers of the eccentric-rod pins and the center of the eccentrics. The link is influenced directly by one or the other of the eccentrics, regardless of the position in the link occupied by the link-block. In Fig. 64 the link-block

stands at its farthest point away from the shaft or axle, and the lead opening is therefore the greatest.

If the link be now lowered, the backing eccentric-rod will begin to pull the link back, and, as the forward eccentric-rod approaches the central line of motion *C D*, it will also draw the link back so that when the link and block occupy the position of full gear the lead opening will be less. When the crank-pin is on the back center as in Fig. 65, the eccentric centers will be on the opposite side of the center of the axle (*line A B*) and the rods will be crossed as explained above. When in this position with the link-block in mid-gear, the latter is closer to the axle or shaft than it would be in any other position of the link, and consequently the lead opening is greatest. If the link be now lowered, the forward eccentric-rod will approach a horizontal position—pushing the link (and link block) away from the axle, reducing the lead opening. Raising the link from a position of mid-gear to full backward gear has a similar effect with the crank-pin on either center If both eccentric-rods were worked from a common center, viz., the center of the shaft or axle, then the link could be raised or lowered when the crank occupied either center without moving the link-block.

Short eccentric rods will increase the tendency toward greater lead opening as the link-block approaches the center of the link.

Increasing the throw of the eccentrics has the same effect, as it throws the centers of the eccentrics farther apart and hence farther to one side or the other of the line *A B*.

Slip of the Link.

As the link-block receives the pin in the lower rocker-arm,

the block moves through the same arc of a circle as the pin which is nearly straight or horizontal—see the upper arm of the rocker shaft in Figs. 66, 67 and 68. The saddle-stud being located a little back of the center of the link, together with the action of the eccentric rods, causes the link to move slightly in a vertical direction at certain parts of the stroke, thus causing the link to *slip* on the link-block.

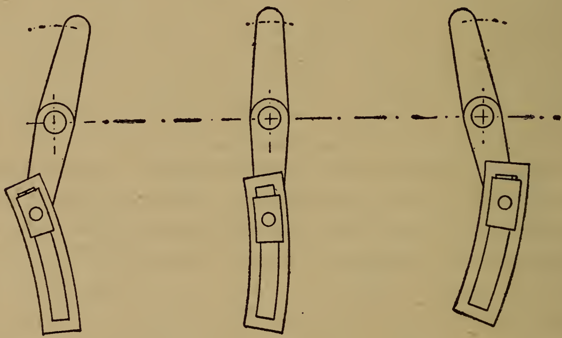


FIG. 66. FIG. 67. FIG. 68.

Figs. 66, 67 and 68 represent the slip of the link. The drawings, however, show a greatly exaggerated case for the purpose of more clearly illustrating the meaning and cause of "slip." We will now consider the relative positions of the various members of a link-gear when setting the gear without a rocker-shaft. We will assume that the engine is to run in the same direction relative to the position of the link as before, that is, when the link is down the engine is to run

under and vice versa. The eccentric-rods have the same names as before, viz., the one attached to the upper end of the link is the forward eccentric-rod, and that attached to the lower end of the link, the back eccentric-rod. When the link is down therefore it is said to be in full forward gear. After placing the link in this latter position, turn the crank and full sides of both eccentrics to the dead-center nearest the cylinder as shown in Fig. 69. As there is no rocker shaft in this case, the direction of the engine will correspond to the direction in which the eccentrics are turned. We wish the engine to run forward (under) when the link is down, therefore we turn the forward eccentric in the *same* direction we wish the engine to run., viz., under and until the valve opens the *forward* port to the amount of the lead. The several parts will then occupy the positions shown in Fig. 70. Fix the forward eccentric to the shaft, then place the reverse-lever in position of full back gear. This will raise the link to the position shown in Fig. 71, and again open the back port.

Now, when the engine runs backward it is to run *over*, therefore we turn the back eccentric in the same direction the engine is to run as before, this time turning it "over" until the valve opens the *forward* port to the amount of the lead as before. The several parts will then occupy the positions shown in Fig. 72. Again place the reverse lever in the position of full forward gear and note the lead opening. If it has been changed by setting the back eccentric, move the forward eccentric a trifle to equalize the lead, then fix both eccentrics to the shaft.

The next operation is to equalize the lead between the forward and back centers and in both forward and back gear,

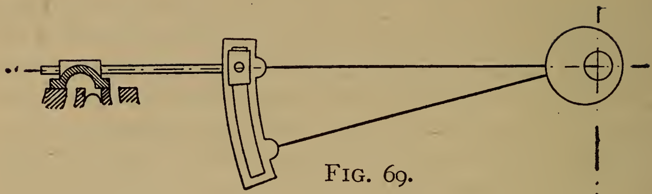


FIG. 69.

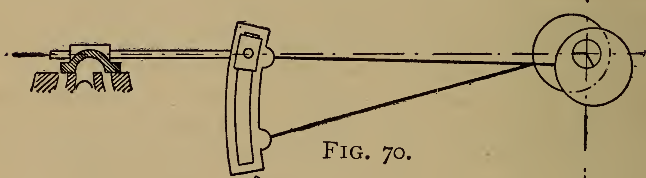


FIG. 70.

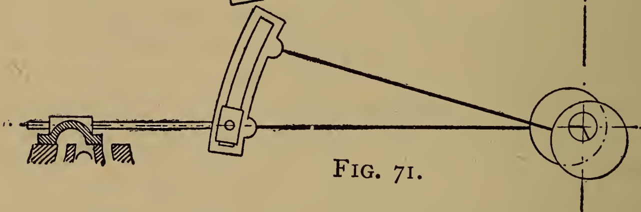


FIG. 71.

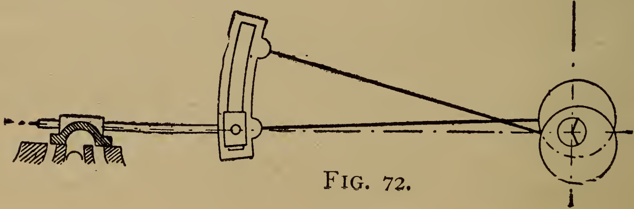


FIG. 72.

in the same manner as previously described except that as the present type of gear has no rocker shaft, the direction of the valve will be the *same* as that of the eccentric actuating it, therefore the directions given in connection with the previous type of link gear in the form of a table must be reversed when applied to a gear without a rocker-shaft. The equalization of the cut-off is accomplished in this gear in precisely the same manner as in a link-gear having a rocker-shaft.

Before concluding the setting of a link-motion there is another problem sometimes met with in connection with this work and that is, placing the crank on the dead-center (for the purpose of setting and adjusting valves) when the axis of the cylinder is above the center of the crank-shaft or axle. In the present locomotive practice, this very often becomes necessary, and sometimes in connection with semi-portable hoisting engines. Should a job of this kind present itself, obtain a good sized piece of paper or a smooth board large enough to receive a diagram as shown in Fig. 73, which is to be drawn to scale and as large as possible.

Suppose the axis of the cylinder is two inches above the center of the axle. First draw the line *a b*, representing the axis of the cylinder, then draw the line *c d* parallel to *a b*. Set the compasses to the length of the crank (the center of the axle to the center of the crank-pin), and with one leg placed on the line *c d* at *e*, describe the circle as shown which represents the path of the center of the crank-pin, *e* representing the center of the axle. Next, set the compasses to the length of the connecting-rod *plus* the length of the crank, and with one leg placed at *e* describe the arc *n o*, cutting the line *a b* as shown. Now set

the compasses to the length of the connecting-rod *minus* the length of the crank and with one leg placed at *e*, describe the arc *P Q*. From the point of intersection of the arc *n o*, and the line *a b*, draw the line *R* through the point *e* and from the point of intersection of the arc *P Q* and the line *a b*, draw the line *S* through the point *e* and extend it through the circle as shown. The points where the lines *R* and *S* respectively cut

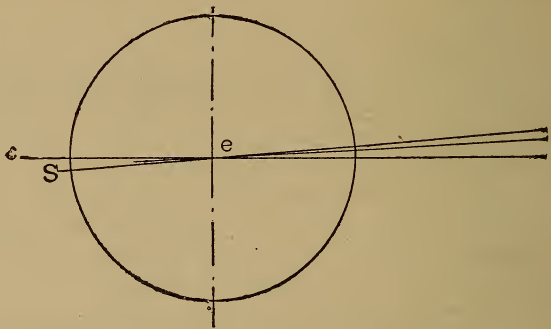


FIG. 73.—(*Completed on opposite page*).

the circle will represent the true forward and back dead centers.

Having found the true dead centers, the crank-pin may be brought to these points in the following manner: If the floor close to the crank is level (both ways) all well and good, but if not, a straight, smooth board should be levelled close to the crank and on the floor. With a bar and trammel point, obtain the distance between the floor (or board) and the center of the axle. Measure on the drawing the distance from

the line *c d* to the point where line *R* cuts the crank-pin circle and raise the trammel point on the bar to the same (actual) distance—having previously marked the first position of the trammel point on the bar. Have the crank turned to the forward center, or close to it, and then with one end of the bar on the floor (or board) have the crank turned slowly until the center of the crank-pin comes opposite the trammel point. The crank will then occupy the true forward center.

Now measure the distance from the line *c d* to the point

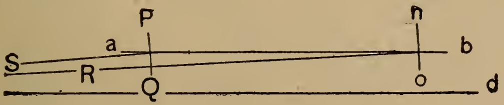


FIG. 73.—(*Completed on opposite page*).

when the line *S* cuts the crank-pin circle (the lower side of the circle farthest from the cylinder). Lower the trammel point on the bar a like amount *below* the first position on the bar. Have the crank-pin turned to the approximate back center and then brought to the exact position the same as for the forward center, when the crank will occupy the true back center. Lost motion should in all cases be taken up, as explained in connection with the setting of an eccentric.

Setting Corliss Engine Valves.

The Corliss valve-gear with its releasing mechanism, differs materially from the types of gears already illustrated, and as an engineer must understand the duty of each member of a valve-gear before he can expect to successfully adjust it,

it may be well first to consider the construction and operation of a Corliss valve-gear.

The exhaust-valves in a Corliss engine are, in operation, the same as the semi-rotary valves. The exhaust valves

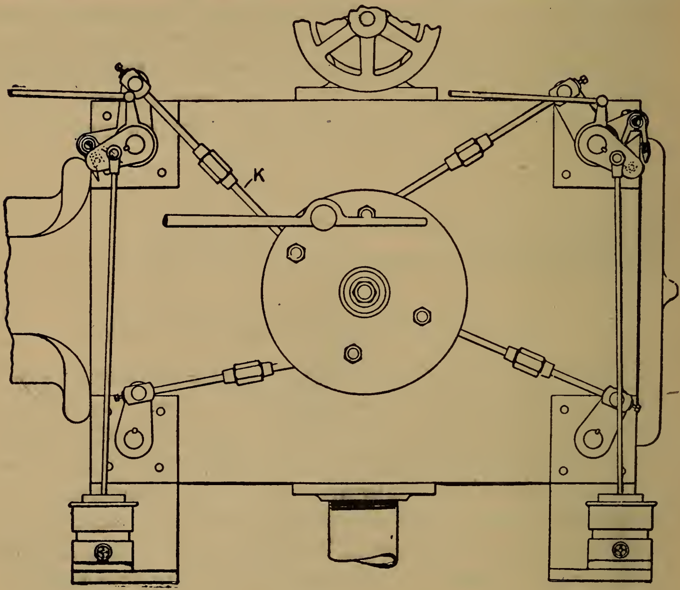


FIG. 74.

receive motion from the wrist-plate by means of the rods connected to it, and a single crank-arm fixed on the outer end of the valve-stem as shown in Fig. 74.

The drawings illustrate the exhaust-valve mechanism in a

sufficiently clear manner to render further explanation unnecessary.

The mechanism employed to open and release (close) the steam-valves embraces the most important features of a Corliss valve-gear. On the valve-stem and next to the yoke is placed a bell-crank lever, *A* Fig. 75. At the end of the horizontal arm of the bell-crank lever is the hook, *B*, which works

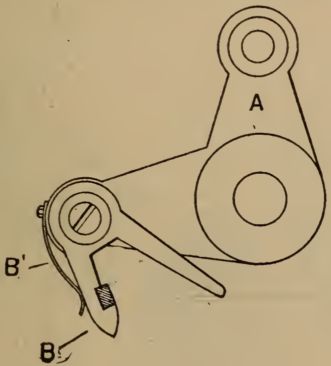


FIG. 75.

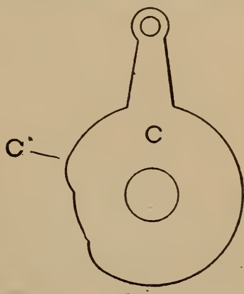


FIG. 76.

freely on the stud. On the valve-stem and placed next to the bell-crank lever is the disc *C* Fig. 76, provided with a projection C^1 and having an upwardly extending arm to which is connected one end of one of the rods from the governor. At the outer end of the valve-stem is placed the valve-stem crank *D*, Fig. 77, which carries at its outer end the catch-block D^1, which is engaged by the hook *B* on the end of the bell-crank lever. To the valve-stem crank *D* is connected the rod D^2

from the dash-pot. The operation of this mechanism may be understood by referring to Fig. 78 which represents the various members in the position they occupy at the commencement of the stroke of the piston. The disc, operated by the governor, is in a position to allow the hook to move to its highest position, or that position corresponding to latest cut-off, before being tripped by the projection C^1, Fig. 76.

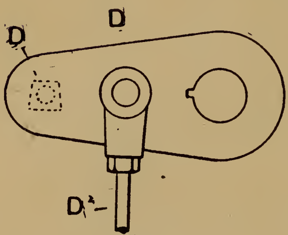


FIG. 77.

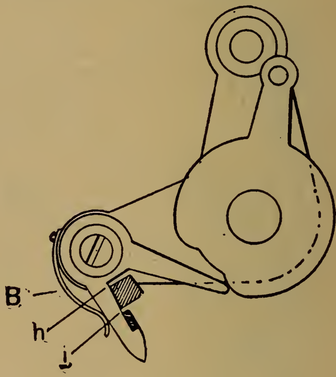


FIG. 78.

It will also be noticed that the hook has engaged the catch-block on the valve-stem crank or arm. Now as the piston moves forward in the stroke, the bell-crank lever is turned round on the valve-stem by the rod K, Fig. 74, from the wrist-plate. The horizontal arm of the bell-crank lever carrying the hook, together with the arm on the valve-stem begin to rise and continue so to do until arriving at the position shown

in Fig. 79. By an inspection of both Figs. 78 and 79, it will be seen that the inner member of the hook has followed the periphery of the disc *C*, and is held in the position shown in Fig. 78 by the flat spring B^1, which keeps the hook engaged with the block until reaching the position shown in Fig. 79. As stated, the inner member of the hook follows the periphery of the disc operated by the governor, until arriving at the position shown in Fig. 79. At this point the inner arm

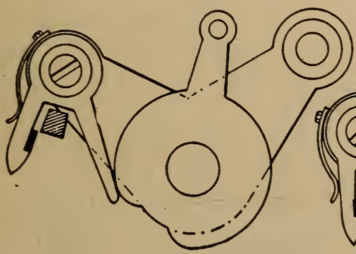


FIG. 79.

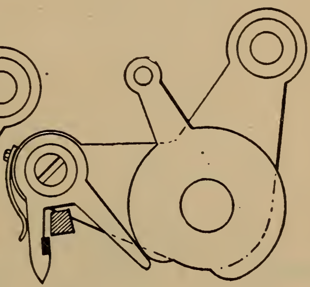


FIG. 80.

of the hook comes in contact with the projection on the disc, which forces the former farther away from the center of the disc, and this movement also causes the hook to release the catch-block carried by the arm on the valve-stem. The arm on the valve-stem being now disengaged from the hook, is rapidly drawn to the position shown in Fig. 74, by the dash-pot and the rod D^2, which causes the valve to close the steam-port, thus effecting the cut-off. From an inspection of Fig. 79 it is evident that the hook is made to release the arm on the

valve-stem, when the inner member of the hook reaches the projection on the edge of the disc operated by the governor. Therefore if the disc be moved to the left, as shown in Fig. 80, the hook can not raise the valve-stem arm to the position shown in Fig. 79, but releases it earlier in the upward stroke of the hook. As the point of release of the catch-block D^1 marks the closing of the port, and as it is earlier in Fig. 80

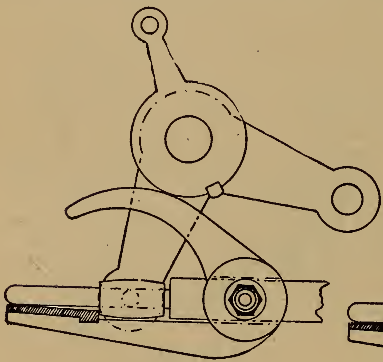


FIG. 81.

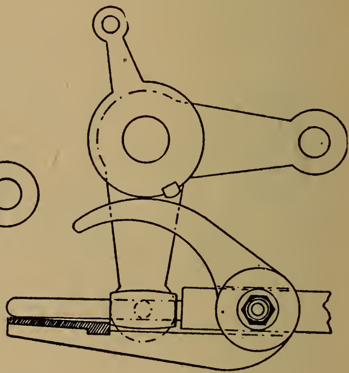


FIG. 82.

than in Fig. 79, it follows that the cut-off will be earlier in the stroke of the piston in Fig. 80 than in Fig. 79.

The foregoing illustrations represent the operation of nearly all forms of Corliss gears, the differences in gears found on engines in use being practically in details of construction, the same principle of operation being embodied in all; therefore it is not necessary to analyze here all forms

of Corliss releasing gears*, for if an engineer thoroughly understands the construction and operation of one design, it will not take him many minutes to fully comprehend the operation of any other design,

The mechanism shown in Figs. 81, 82 and 83 is that of the Reynolds-Corliss engine. Fig. 81 represents the position of

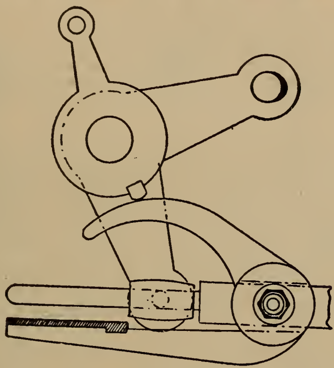


FIG. 83.

the several parts at the commencement of the stroke of the piston. In Fig. 83 the curved arm of the hook has engaged the projection on the disk operated by the governor and the hook has just "let go" of the catch-block, which in this case is carried by one of the arms of the bell-crank lever which is secured to the valve-stem. To the other arm is connected the rod from the dash-pot. Fig. 83 represents the position of the

*For the illustrations and descriptions of the various modifications of Corliss engine valve-gears, see *The Engineer*, Nov. 15, 1899.

several parts when the port is wide open and the hook is at the extreme outward end of its travel. When about to set a Corliss gear the first thing to be done is to "centralize" the various parts and equalize their movements. First, place the wrist-plate and rocker-arm plumb, as shown in Fig. 84, then with a straight edge and scriber mark the position of the

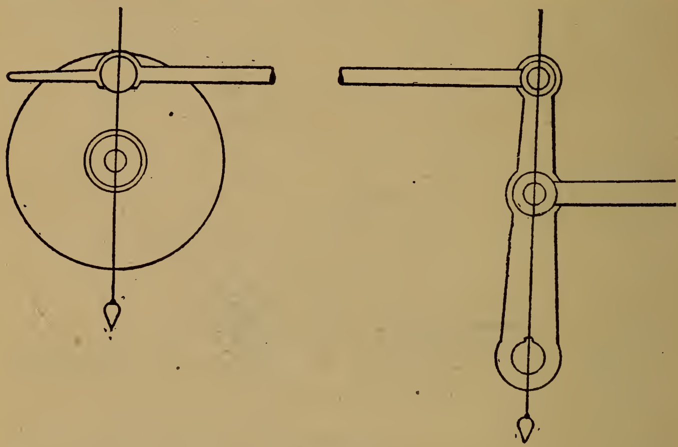


FIG. 84.

wrist-plate as at *a* and *b*, Fig. 85. Now turn the eccentric on the shaft to the dead-center farthest from the cylinder and make a very light mark as at *c*, Fig. 86, in line with the mark *a* on the wrist-plate. Then turn the eccentric to the opposite dead-center and in the same manner make the mark *d*, Fig. 87. With a pai. of dividers or a flexible scale measure the distance from the mark *b* to the marks *c* and *d*. If the mark

d should be nearer *b* than the mark *c*, then the eccentric-rod must be lengthened a trifle. The eccentric is then to be placed on the dead-center as before, and measurements again

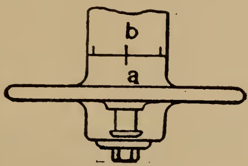


FIG. 85.

made. If it is then found that the marks *c* and *d* are the same distance away from the mark *b*, then the wrist-plate (mark *a*) will move an equal distance either side of the mark *b*, which proves the eccentric-rod to be of proper length. The last of the fine marks made on the stud represented by *c* and *d* are then to be made deeper and more permanent.

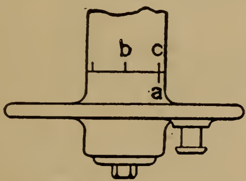


FIG. 86.

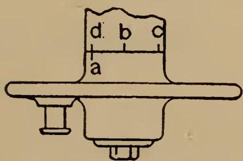


FIG. 87.

The next step is to equalize the lap of the steam valves. Presuming the valve-chest covers or bonnets have been removed, the end of the valve on the front side of the engine will appear as shown in Fig. 88 revealing the marks *e*, *f* and *g*.

These marks are usually placed there by the builders of the engine when the latter is set up in the shop, but if they do not appear they may be made by the aid of a machinist's square and the table of lap of valves.

The mark *e* represents the edge of the valve, *f* the edge of the steam-port, and the distance between marks *f* and *g* represents the amount the valve should lap over the edge of the

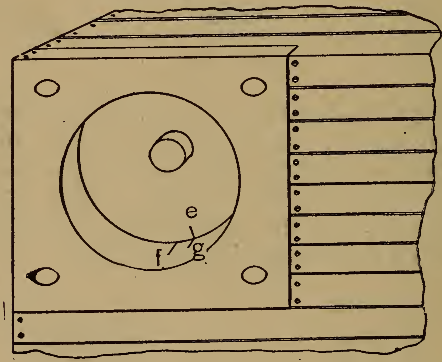


FIG. 88.

port when the wrist-plate stands plumb. Now, after setting the wrist-plate plumb by means of marks *a* and *b*, Fig. 85, and seeing that the hooks engage the valve arms, the lines *e* and *g* should be exactly in line with each other, at both ends of the cylinder—that is, both valves should have the same lap.

If the lines do not coincide, the radial rod connected to the

bell-crank on the steam valve-stem must be adjusted until the proper position of the valve is reached.

The exhaust-valves are next to receive attention and in this case let *e* represent the edge of the valve and *f* the edge of the port as before. If the line *e* is not in line with *f*, the valve must be moved until these lines coincide, which may be accomplished by adjusting the right and left adjustment in the rod connecting that valve with the wrist-plate. The exhaust valve at the opposite end of the cylinder is to be set in the same position, and in like manner.

Having "centralized" the valves and valve-gear, it is a good plan to put in the starting bar, before proceeding further and move the wrist-plate so that the lines *a* and *c*, Fig. 86, are in line. The hook of the valve to be raised should then occupy the position shown in Fig. 78 and the point to be observed is that the clearance, or spaces *h* and *i* respectively are about equal. If not they may be made so by means of the right and left adjustment in the rod, connecting that valve with the dash-pot.

By means of the starting bar open the valve, the clearance having just been equalized, until it is released. Again bring the marks *a* and *c* in line and again examine the clearance or spaces *h i* Fig. 78 ; if they are the same as before then the dash-pot at that end of the cylinder seats properly. The same operations are to be gone through with at the opposite end of the cylinder.

We are now ready to set the eccentric.

Place the crank and the full side of the eccentric on the dead-center nearest the cylinder and drop the reach-rod on the stud in the wrist-plate. We will assume that the engine

is to run "over." Now it will be noticed by referring to Fig. 74, that to open the steam-valve at the head-end of the cylinder, or the end of the cylinder farthest from the crank, the wrist-plate must move in the *same* direction as that of the piston, hence we turn the eccentric around the shaft in the same direction in which the engine is to run, and until the valve at the head-end of the cylinder has opened the port to the amount of the lead, which will be indicated by the position of the lines *e* and *f* Fig. 88. Fix the eccentric to the shaft at this point. An easy way to set off the lead when setting the valve is: Take the distance between the lines *f* and *g* plus the lead, in the dividers, then place one leg of the dividers at line *g*, and have the line *e* on the valve brought to the other point of the dividers, when the valve will have opened the port to the right amount. The engine must now be turned to the opposite dead-center, and the amount of lead noted. If the lead is the same on the back center then the steam-valves will have been set correctly. We will again turn our attention to the exhaust valves, this time for the purpose of adjusting them for compression. As the exact amount can only be determined satisfactorily by trial we will say that our engine is to have two and one-half inches compression, that is, the exhaust-valves must be set so as to close the exhaust-port when the piston is within two and one-half inches of the end of the stroke. To do this we measure off two and one-half inches from each end of the guides and make a line with the scriber. Now turn the engine in the direction it is to run, until the cross-head has nearly completed its outward stroke and has reached the line on the guide. By means of the lines on the end of the valves and

the right and left adjustment in the rod, connecting that valve with the wrist-plate, have the valve moved (if it needs moving) until the line representing the edge of the valve comes exactly opposite the line representing the edge of the port. This marks the point of exhaust closure for that end. Then turn the engine around in the same direction until the cross-head reaches the line at the opposite end of the guides. The opposite exhaust-valve is then set in precisely the same manner as the first.

Now we are ready to adjust the governor to produce an equal cut-off at each end of the cylinder. On the spindle of most Corliss engine governors will be found a stop device, in the form of a loose pin, or a removable collar. This device is for the purpose of preventing the governor from reaching its lowest position, for when it reaches the latter position the catch-block on the valve-stem arm should not be engaged by the hook. Should the governor belt break or slip badly, the governor would stop and reach its lowest position on the spindle, and as the valves cannot be opened when it is in this position the admission of steam to the cylinder is entirely shut off and the engine will come to a standstill.

It will be apparent from the foregoing that the stop at the lower part of the governor spindle should be rendered inoperative, either by hand or automatically, as soon as the engine has attained full speed, and should again be placed in active position when about to stop the engine, as at noon or at night.

As the stop device just mentioned determines the lowest position of the governor at which the valves should hook on, we will block up the governor and insert the stop. Un-

hook the reach-rod from the wrist-plate, and by means of the starting-bar move the wrist-plate over until the lines a and c, Fig. 86, are nearly opposite each other. The head-end valve should now have opened the port nearly wide, which may be ascertained by the marks on the end of the valve. Now adjust the governor-rod so that the projection on the disc operated by the governor will come in contact with the inner member of the hook, and so that the valve will be tripped or released when the marks a and c, Fig. 86, are exactly in line. As all governors do not move an equal amount to produce a given change in the point of cut-off, it will be safer to hook the reach-rod on the wrist-plate and have the engine turned in the direction it is to run, until the head-end valve is released. Then to adjust the cut-off at the crank-end, measure the distance the piston has moved in the forward-stroke, beginning at the cylinder end of the guides. Then lay off the same distance, beginning at the crank-end of the guides. Now have the engine turned round in the *same* direction as before, until the cross-head nearly reaches the last mark made on the guide, which will be nearer the cylinder-end of the guides.

Unhook the reach-rod and turn the wrist-plate round until the marks a and d, Fig. 87, are nearly opposite each other, then adjust the length of the rod from the governor until the projection on the disc operated by the governor comes in contact with the inner member of the hook, and, so that the valve will be released when the cross-head reaches the last mark referred to and the marks a and d are exactly in line. Then will both valves cut off at the same point in the forward and return strokes respectively. In order that the same

mean effective pressure, and consequently the same amonnt of work be performed in each end of the cylinder, the cut-off at the crank-end should be a trifle later than at the head-end. This is due to the fact that the piston area is reduced an amount equal to the area of the piston-rod.

As the difference in the cut-off required is small and is dependent upon the area of the piston-rod, this adjustment of the cut-off can be more accurately made by the aid of the

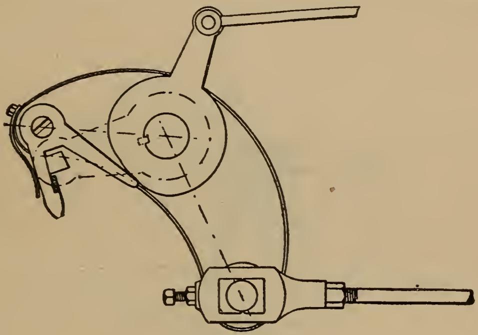


FIG. 89.

indicator. At the upper part of the governor spindle, and a few inches above the counter-weight is another stop in the form of a collar, usually held in place by a set-screw, and is for the purpose of limiting the highest position of the governor. This collar should be placed at such a height, that when the governor is blocked up to it, the steam-valves cannot hook on. In case of breakage of the line shaft or main belt, the engine upon being relieved of its load will immediately run

faster and until the counter-weight reaches the collar referred to, when the admission of steam to the cylinder being entirely shut off, the speed of the engine will at once slacken to the normal no-load speed. The valve-chest covers may now be put on, when the work of setting and adjusting the valves will be completed.

In the foregoing it has been assumed that the type of valve-gear employed was the same as shown in Fig. 74. If,

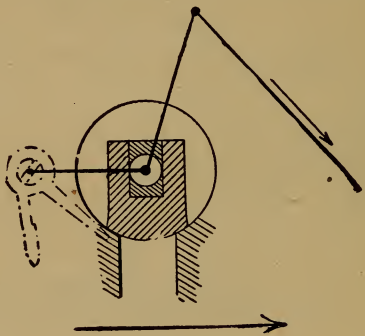


FIG. 90.

however, it had been of the type shown in Fig. 89, we should have had to proceed a little differently when setting the eccentric. The difference referred to may be understood by referring to Figs. 90 and 91.

Fig. 90 represents the principle of the gear which has just been described. It will be noticed (see Fig. 74) that as the eccentric, eccentric-rod, wrist-plate, etc., move toward the crank, the valve opens the port at the head-end of the cylin-

der, therefore the piston, eccentric and wrist-plate move in the *same* direction. This explains why the eccentric in this case was moved in the same direction in which the engine was to run.

Turning to Fig. 89, the principle of which is represented in Fig. 91, we find that when the piston moves forward or towards the crank (this direction being indicated by the large arrows) the wrist-plate and eccentric must move in the *opposite* direction to that of the piston, in order to open the

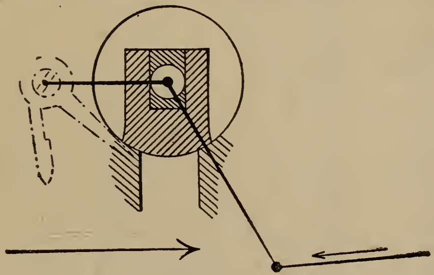


FIG. 91.

port at the head-end of the cylinder. It is evident from this, that when setting the valves of a Corliss engine provided with a releasing gear of the type shown in Fig. 89 the eccentric must be turned in the *opposite* direction to that in which the engine is to run, until the valve opens the port to the amount of the lead.

The work of setting the valves of a Corliss engine having two eccentrics is not particularly complicated as many engineers seem to think that it is. After inspecting the type

Table Showing Lap and Lead of Valves of Corliss Engines.

Size of Engine	Revolutions per minute	Wrist-Plate in Central Position: Steam Valves Lap.	Wrist-Plate in Central Position: Exhaust Valves Lap.	Crank on Dead-Center: Steam Valves Lead.	Trial Compression to be Verified by the Indicator.
8 × 24"	100	5-32"	3-64"	1-64"	1½"
10 × 24	90				1¾
12 × 30	90	3-16	1-16		1⅞
12 × 36	80				2
14 × 36	80	1-4	1-16		2⅛
14 × 42	80				2¼
14 × 48	75		3-32		2½
16 × 32	85	5-16			1⅞
16 × 36	80				2
16 × 42	75				2¼
16 × 48	70			1-32	2½
18 × 36	75	3-8			2¼
18 × 42	70				2½
18 × 48	65				2⅝
20 × 42	70		1-8		2¼
20 × 48	65				2½
20 × 60	65				3
22 × 42	70	13-32			2⅛
22 × 48	65				2½
22 × 60	65				2¾
24 × 42	80				2¼
24 × 54	72				2⅝
24 × 60	60	7-16			2⅞
26 × 48	65		5-32		2½
26 × 60	60			3-64	2¾
28 × 48	65				2¾
28 × 60	60				3
28 × 72	55				3¾
30 × 48	65	15-32	3-16		3¼
30 × 60	60				3½
30 × 72	55				3¾

of releasing-gear employed and knowing in which direction the engine is to run, finding the direction in which to turn the eccentric becomes a very simple matter. When setting the steam-valves we have one eccentric to turn as in the case of the single eccentric engine* and when setting the exhaust valves another eccentric must be turned, but this does not add complication to the work, although it requires a little more time. The full side of the steam and exhaust eccentrics when set, stand approximately opposite each other, the exact position, of course, being determined by the required position of the valves. The work of centralizing the position of the various parts, equalizing the movements and setting and adjusting the gear is precisely the same as in the case of a single-eccentric engine.

After setting the valves and making the final adjustments the engine should be started under steam and the work verified by the use of the indicator.

This is especially true where the valves are set when the engine is cold.

Setting the Valves of the Brown Engine.

(Side Shaft Pattern.)

The Brown engine, as will be seen by an inspection of the drawings, is a slide-valve engine in which valves of the grid-iron or multiported type are employed. The operation of the valves and method of setting them, however, differs considerably from that in what is commonly known as a slide-

* For the practical limit of cut-off in the single-eccentric engine see *The Engineer* November 15, 1899.

valve engine. As far as the distribution of steam in the cylinder, and consequently the appearance of an indicator diagram taken from a Brown engine are concerned, they are identical to those obtained in a Corliss engine. Fig. 92 represents a side view of the valve gear at the cylinder. It

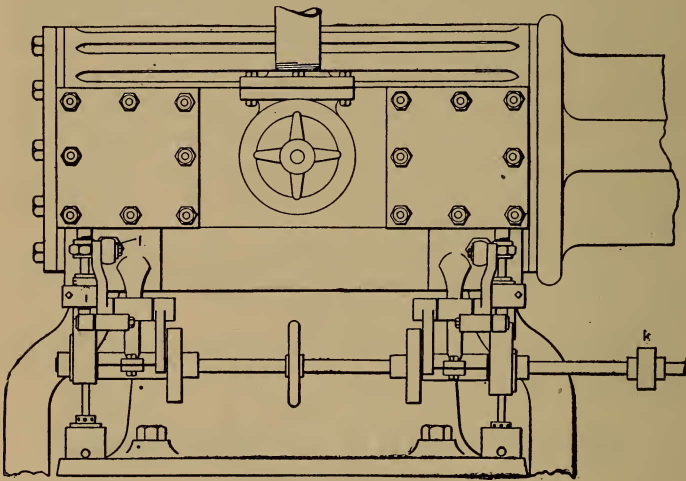


FIG. 92.

will be noticed that the eccentrics in this engine are at the cylinder instead of being fixed on the main shaft. The side shaft is driven by means of a train of gears (three) from the main shaft and a pair of bevel gears located under the main bearing, the necessary bearing for these gears and side shaft being attached to the main bearing pedestal. In order that

the operation of the steam and exhaust-valves may be made more clear we will consider their functions separately, beginning with the steam-valves, a side sectional view of which is shown in Fig. 93. The steam-valves are carried by and at the upper end of the valve-stem *s*, the lower end of which is attached to the upper end of the stirrup *a*. In the stirrup is located the hook *b*, and attached to the lower end of the stirrup is the rod from the dash-pot. The lever or arm *c* is carried by the auxiliary shaft *d*, Fig. 93, and through which the governor changes the position of the arm. The operation of the steam-valves is as follows:

The eccentric *e*, carried by the side shaft, revolves in the direction indicated by the arrow, and after passing the lower center begins to raise the lifter *f*, the inner end of which engages the hook in the stirrup, thus raising the valve also. The valve continues its upward movement until the lower end of the hook engages the arm *c* on the governor-shaft. At this point the hook is released from the lifter, and the dash-pot at once draws the valve downward, closing the ports and effecting the cut-off.

It will be seen from this that the point of cut-off is regulated by the governor in changing the position of the arm *c* and causing the hook to be tripped, thus releasing the valve earlier or later during its upward movement, according to the load on the engine. The exhaust-valves lie in a horizontal position and immediately below the bore of the cylinder, as shown in Fig. 94. These receive motion from the side shaft by means of a cam-wheel *g*, in the groove of which is a roller carried at the lower end of the rocker-shaft *h*. To the upper end of the rocker shaft is connected the exhaust-valve stem.

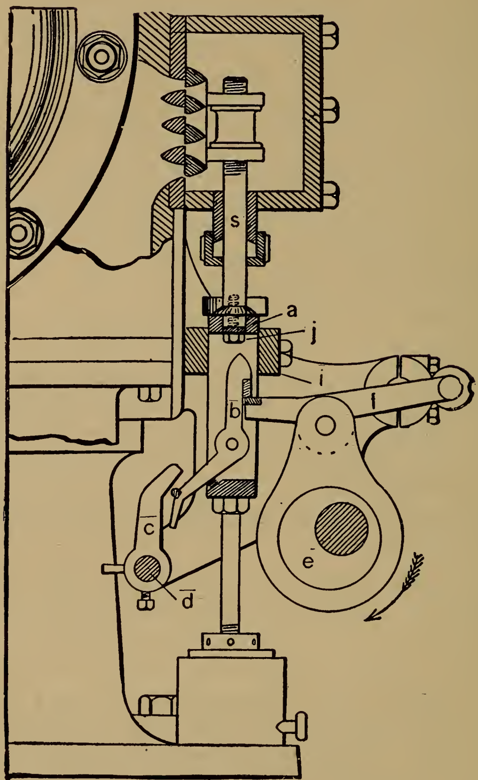


FIG. 93.

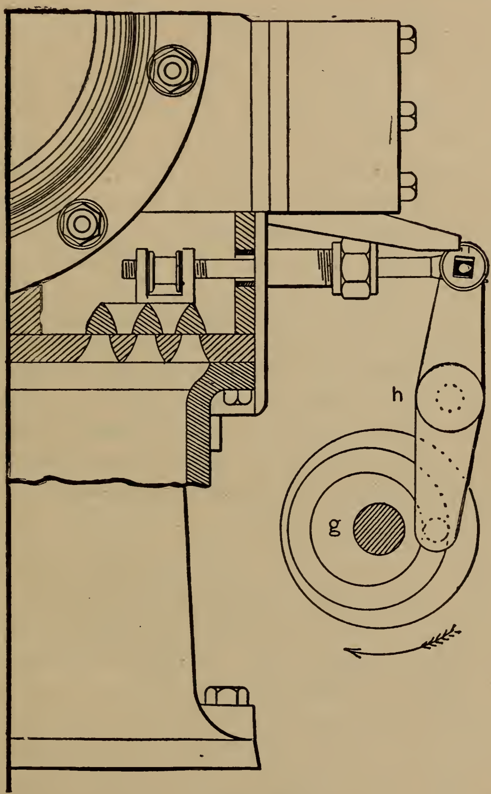


FIG. 94.

When a Brown engine is first erected the valves are proper*l* set and all parts accurately marked ; therefore should the valve-gear become changed by the mere slipping of an eccentric or cam-wheel, the work of resetting the valve or valves becomes a very simple matter and one not requiring any particular skill, for in this case it is only necessary to bring the marks into their original position and tighten the set-screws. In case the trouble is due to wear, or to the presence of numerous marks, which are too often found on this type of engine, rendering it impossible to determine the position of the valve in the chest by means of a given mark, a different mode of procedure must be resorted to.

If the engine is undergoing general repairs and time is not of such importance as when running, the removal of the cylinder-head and piston will greatly facilitate the work of setting the valves correctly, as both the steam and exhaust-valves may then be seen through the ports, and their exact position determined. However, the more probable method of resetting the valves of a Brown engine will be one that does not necessitate the removal of the cylinder-head and the piston, especially the latter, so we will consider such a method.

We will assume now that the engine has been running and the several parts are correctly assembled as in Fig. 92. After placing the engine on the dead-center farthest from the cylinder, adjust the height of the stirrup at the crank-end of the cylinder by means of the threaded end of the rod from the dash-pot, so that the lifter will just engage the hook when the eccentric is on the lower center, or in its lowest position. Mark the height of the stirrup at the top of the guide *i*, Fig. 92. Remove the guide and the cap screw *j*,

then raise the valve-stem clear of the stirrup and remove the chest, valve and stem from the engine, and lay on a table so that the valve may be seen. Remove the stem from the nut in the back of the valve, then, after taking the valve out of the chest, return the valve-stem to the nut and place the valve against its seat on the engine, connect the valve-stem to the stirrup when the valve will occupy its normal position minus the valve-chest. After raising and lowering the valve as the case may require and until the valve has the proper lap, mark the position of the stem relative to the top of the stirrup; this may be done by making a mark on the stem close to the stirrup and another on the latter. Now turn the eccentric in the direction in which it runs until the lifter has raised the valve a sufficient distance to open the ports to the amount of the lead. Mark the height of the stirrup at the top of the guide as before. Then the distance between these two marks on the stirrup will indicate the lap of the valve plus the lead, see Fig. 92. Again place the valve on the table, being careful not to move the valve-stem in the nut in the back of the valve.

Unscrew the stem from the nut *counting the number of revolutions made until the stem leaves the nut.* Place the valve in the chest and again insert the stem in the nut giving it the *same number of turns as was required to take it out.*

The chest, valve and stem are now put in place on the engine, and the valve-stem inserted in the stirrup and secured by the cap-screw, bringing the lines on the stem and stirrup into proper position. After bringing the side shaft to its proper running position, which will be indicated by the clutch *k*, Fig. 92, the eccentric may be turned in the direction in

which it runs until the lower mark on the stirrup registers with the top of the guide. The eccentric being fixed in this position, the valve will have opened the port to the amount of the lead. The same operation is to be repeated at the head-end of the cylinder.

In the case of the smaller and medium sizes of Brown engines, it may prove a saving in time to remove the cylinder-head, for this may be found easier than removing the valve-chest, and by so doing the steam and exhaust-valves at the head-end may be set by sight from the inside of the cylinder, through the port and without disconnecting the valve-gear. All that is necessary in this case is the removal of the guide *i*; then loosen the cap-screw *j*, Fig. 93, which will allow the valve-stem to be turned in the nut in the back of the valve.

The mechanism employed in operating the exhaust-valves is extremely simple, and so constructed that derangement is practically impossible, except that due to the slipping of the upper arm of the rock-shaft, or the cam-wheel, and these can be quickly adjusted without disconnecting any of the members of the valve-gear. Suppose the usual marks on the side shaft have been removed. Take off the collar *l*, Fig. 92, and two marks will be found as shown in Fig. 94. The distance between these marks represents the lap of the exhaust-valve.

With the aid of the gauge or tram as shown, the valve may be brought to its original location in the following manner: Turn the cam-wheel so that the lower arm of the rocker-shaft is in its extreme position nearest the cylinder, then place the tram in the position shown and move the upper arm until the mark nearest the cylinder registers with

the end of the tram. Secure the upper arm of the rocker-shaft at this point.

To set the exhaust-valve, turn the engine in the direction it is to run until the cross-head arrives at the point where compression is to begin. If the engine is to have two and one-half inches compression, turn the engine over until the cross-head is within two and one-half inches of the end of the stroke, then turn the cam-wheel on the side shaft in the direction it is to run until the outer mark, see tram Fig. 94, registers with the end of the tram. In this position the exhaust-valve will have just closed the port.

The same operation is of course to be gone through with at the opposite end of the cylinder. If, for any reason, no marks appear at the upper end of the rocker-arm, as would be the case if an entirely new stem had been put in, then the exhaust connections at the under side of the exhaust-chest must be removed and the valve-seat blocked up in place, when the valve may be set by sight from the under side of the valve-seat.

After setting an exhaust-valve in this manner, the tram should be applied and marks accurately made for future use.

To Equalize the Cut-off.

On the auxiliary or governor-shaft, and opposite each stirrup, will be found a vertical arm as at *c*, Fig. 93, the one at the crank-end being held by set-screws only, while the one at the head-end is held by a set-screw and a tapered pin.

Having set the arm at the crank-end so as to admit of the latest cut-off, which should not exceed seven-sixteenths of the stroke, the equalization of the cut-off is effected by moving the arm at the head-end of the cylinder only.

Pulling the tapered pin out allows of a later cut-off, and pushing it in causes an earlier cut-off. After the cut-off (latest) at the crank-end has been established, that at the head-end is to be made the same as the cut-off at the crank-end, and by means of the tapered pin a very nice adjustment of the cut-off may be had.

Reversing the Engine.

The side shaft in a Brown engine should always turn in the same direction, as indicated by the arrow, Fig. 93, regardless

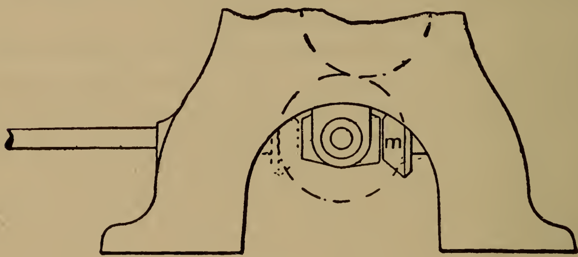


FIG. 95.

of the direction in which the engine runs. It will be seen from this that the direction of the engine is not to be changed by altering the position of the eccentrics on the side shaft, but by removing the bevel-gear *m*, Fig. 95, and placing it in the position represented by the dotted lines. To accomplish this it will be necessary to loosen the set-screws in the several collars and other members of the valve-gear carried by the side-shaft, including the bevel-gear *m*. The crank, of course should be on either one of the dead-centers. Then slide the

side shaft toward the cylinder until the bevel-gear can be removed and placed as shown by the dotted lines. The side-shaft is then to be pushed back to its proper place and the various members brought to their positions by the marks provided for that purpose, except the bevel-gear which is to be set last, and can only be set when the shaft has been brought to its proper running position.

Having all the parts properly set with reference to the side-shaft, and the clutch in its running position, have the side shaft turned in the direction in which it runs until the lower of the two marks on the stirrup at the end of the cylinder, corresponding to the position of the crank, registers with the top of the guide *i*, Fig. 93, as previously described. It should be said that in turning the side shaft upon this occasion, the shaft should be turned from the crank end and so as to keep the clutch up tight and in the working position. With the above mark in proper position at the top of the guide—have the set screws tightened in the bevel-gear. The engine will then be ready to run in the opposite direction.

The cylinder dimensions of the Brown engine closely approximate those of the Corliss engines, therefore the lap, lead, and trial compression given in a previous chapter for the Corliss engines will be found applicable to Brown engines. Setting the valves of this type of engine while hot will not be found to be as practicable as in some other types therefore it is very important that the indicator should be applied soon after the engine is started and the final adjustments of the valve-gear made by the aid of an indicator diagram.

Examination Questions Answered.

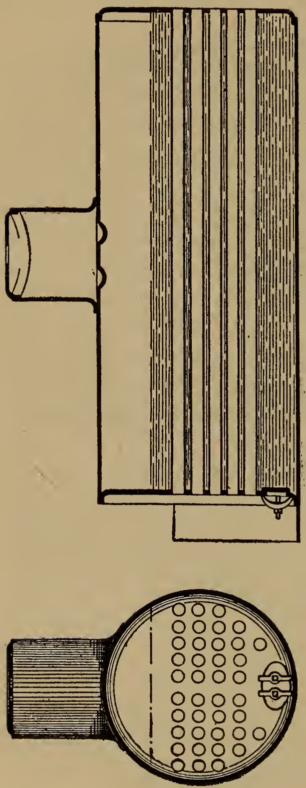
1. What qualities and qualifications should characterize a safe and reliable steam engineer?

In order to become reliable, and a safe person to be in charge of steam machinery, one must be temperate. There is no place in the steam engineering field for a drunkard, and any person aspiring to the position of steam engineer, and who hopes to have charge of a modern steam-plant, cannot afford to use intoxicating liquors as a beverage. He should understand the principles involved in generating steam in a steam boiler, and those involved in a steam engine, pump, condenser and injector, in fact, all the accessories to steam machinery in general use, as well as having a practical knowledge, gained by experience, of the proper care and management of the various apparatus of which a modern steam-plant is composed. He should be in possession of the senses of sight, hearing and smelling, and be at all times observant of things about him. With these qualities combined with the desire to know the cause and effect of the various operations and processes connected with the running of steam engines and boilers and a determination to do everything well, he will possess the qualifications to be looked for as well as those necessary, to become a safe and reliable engineer.

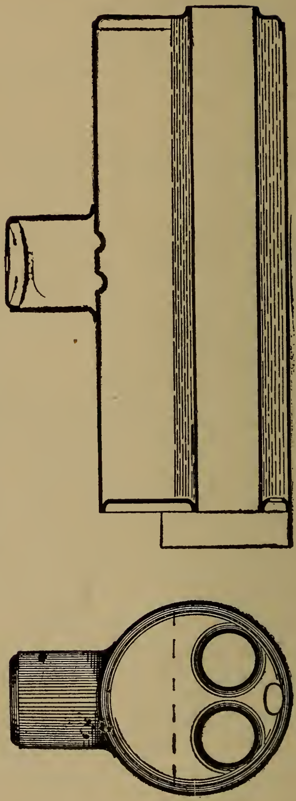
2. (a) What studies besides those of reading and

writing do you consider necessary for one to be proficient in order to become a successful engineer, and (b) what are the duties of an engineer?

(a) Arithmetic, natural philosophy and spelling, in the order given. When the steam engine first became a commercial success and the largest factories then in existence were being equipped with the new motive power, comparatively little was known of the many ways of using steam economically, for the data available were limited, and more or less unreliable. Engineers in those days were expected to know how to start and stop the engine and locate any disorder that might arise in it; that was about all. After these years of advancement and experience it is not unusual that engineers are expected and required to know much more concerning that kind of machinery and apparatus, the care and management of which form their *business*, and possibly their life work. Arithmetic comes first, for with it we can also obtain an additional knowledge of reading, writing, spelling, grammar and punctuation, and it includes the second and fifth branches named. Natural philosophy, or physics, forms the stepping-stone to the profession of steam engineering, embracing all the principles made use of in the construction and operation of every piece of apparatus entrusted to the care of the engineer. (b) The duty of the engineer while in the engine-room is to give his whole time and attention to the care and management of every piece of apparatus in his charge, seeing that the steam pressure is carried uniformly and that the lawful or safe pressure is not exceeded; that the water is carried at the proper level, and not permitted to get too high, nor too low; that the fires are



RETURN TUBULAR BOILER.

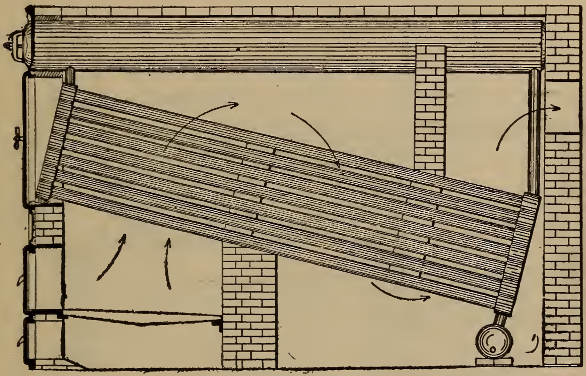


RETURN FLUE BOILER.

properly attended to and the fuel used to the best advantage, and that the journals are regularly oiled and not allowed to get hot and to cut; in short he must keep his eyes and ears open, and be ready to act promptly in case of emergency.

3. *What machine or apparatus in every steam-plant should receive the most careful attention and why?*

The steam boiler. The boiler is, practically speaking, the



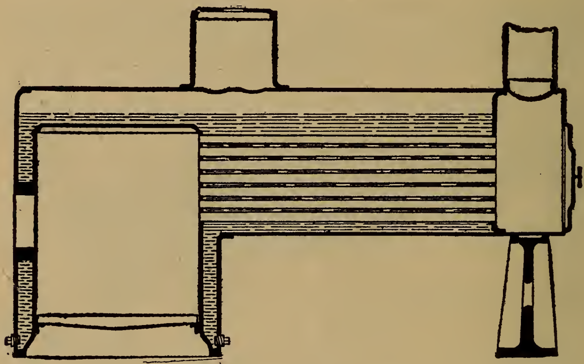
WATER-TUBE BOILER.

source of the energy produced in every steam-plant. The pressure gauge shows the pressure of steam on one square inch of surface, so that the total force tending to pull asunder the plates of a boiler may be obtained by multiplying the number of square inches upon which the steam acts by the pressure indicated by the gauge. In rather small boilers this will be found to be several tons, which easily accounts for the

disastrous effects of boiler explosions. It is due to the enormous force held within its narrow confines, that the boiler should be given the first and most careful attention by the engineer.

4. Name the different types of boilers in common use.

The types of boilers in general use are: Water-tube, return tubular, return flue, locomotive, vertical tubular, drop flue, and Scotch (marine).

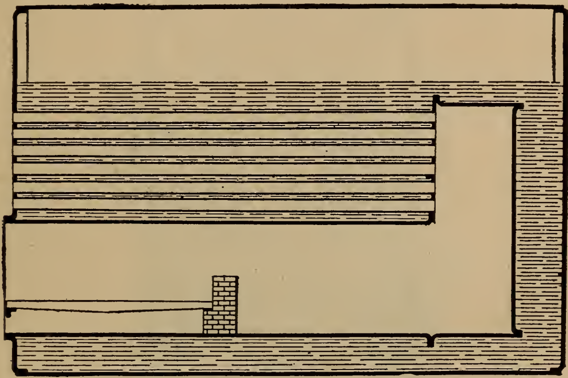


LOCOMOTIVE BOILER.

5. What is the difference between a flue, tubular and water-tube boiler?

A tubular boiler consists of an outer cylindrical shell, into the heads of which are expanded a number of tubes (see return tubular boiler answer to question 3) through which the smoke and gases pass on their way to the chimney. A flue boiler is much the same as the tubular except that the heat-

conducting passages through the boiler are larger, fewer in number and are generally riveted to the heads instead of being expanded into them. The tubes are four inches in diameter or less ; flues are more than four inches in diameter. A water-tube boiler consists of a number of tubes through which the water circulates, the steam rising into a drum at



SCOTCH (MARINE) BOILER.

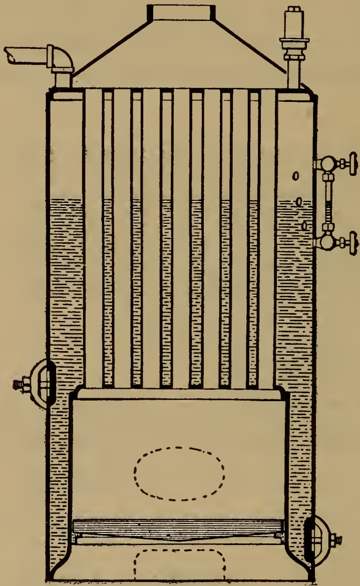
the top. The fire and hot gases surround the tubes in the water-tube boiler.

6. *What is a boiler? a pump? an injector?*

A boiler is a machine for converting water into steam by the application of heat. An injector is a machine for raising and moving liquids by means of a steam-jet. A pump is a machine for raising and moving liquids and compressing air and other gases.

7. *Name the different seams in a boiler.*

The seam extending lengthwise of a boiler or dome, is called the longitudinal seam, those running round the boiler at the heads and ends of the plates are called curvilinear or

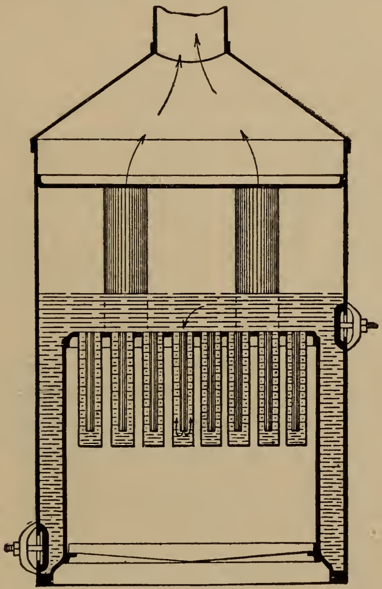


VERTICAL TUBULAR BOILER.

ring seams. The seam at the base of the dome is called the saddle-seam or dome-seam. The seam connecting the cylindrical portion of a locomotive boiler to the fire-box is called the waist, and those in the water legs the leg-seams. The

same applies to the water legs of a vertical boiler, which are also called bottom ring seam, and top ring seam, as the case may be.

8. *What is the difference between a single and double*



DROP FLUE BOILER.

riveted seam? What is meant by the safe-working pressure of a boiler?

A single-riveted seam has but one row of rivets to hold the edges of the plates together, while a double-riveted seam has

two rows, and the triple-riveted seam has three rows. The longitudinal seams are usually double and triple-riveted, the curvilinear or ring seams usually being single-riveted. The curvilinear seams usually resist the pressure of steam against a portion of the boiler head only, while the longitudinal seams must resist a stress tending to pull the plates asunder. The latter joint not being aided by braces, tubes, etc., must resist a much greater stress than the ring seams. The safe-working pressure of a boiler is the highest pressure the boiler is capable of carrying with safety, and is usually taken at one-fifth the bursting pressure. The true safe-working pressure of a boiler cannot be ascertained without taking into account the strength at the seams, particularly the longitudinal seams, for the pressure on them is nearly double that on the ring seams.

9. What is meant by tensile strength?

If the tensile strength of boiler plate is 60,000 pounds per square inch of section, it will require a force equal to 60,000 pounds, applied in the direction of its length, to pull asunder a bar one inch square, or a bar having an area of one square inch, whether it is one inch square or not.

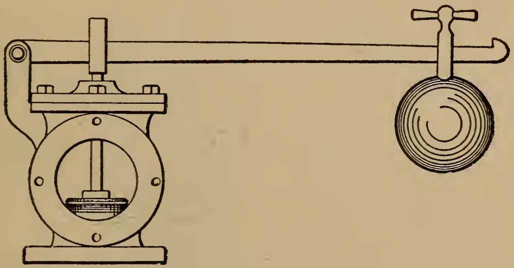
10. What are braces for, and where are they placed in boilers?

To assist the surfaces to which they are attached in resisting the tendency of the steam to force them outward. In horizontal return tubular boilers the braces extend from a point on the shell to the head, for the purpose of holding the flat surface of the head in its proper position, or from bulging outward. Braces also extend from the top of the dome to the sides, and to the top of the shell for the purpose

of relieving the seams of much of the strain due to the pressure of steam. In locomotive and vertical boilers what are known as stay-bolts are screwed into the inner and outer plates forming the fire-box, to relieve these plates of the strain due to the steam pressure. The crown-sheet in locomotive boilers is stiffened by means of crown-bars, which are in turn held up by stays screwed and riveted into the outer shell.

11. How is the safe-holding power of braces calculated?

Multiply 6,000 by the area of the brace at the smallest

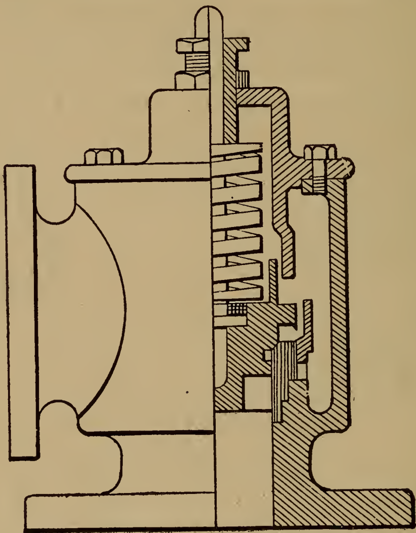


LEVER SAFETY VALVE.

diameter, or at the bottom of the thread of a stay-bolt. The number of braces or stay-bolts is obtained by first multiplying the number of square inches of unsupported surface by the maximum pressure of steam in pounds, then dividing the product thus obtained by the safe-holding power of one bolt. The pitch or distance between the centers of stay-bolts is found by dividing the total area in square inches to be braced by the number of stay-bolts. The square root of the quotient will be the pitch in inches.

12. How many kinds of safety-valves are there? What are the advantages of each kind.

Practically two. The lever safety-valve and the spring valve. The lever valve is the cheaper form of valve, and a little the easier to adjust to a given pressure, but requires a



Spring Safety Valve.

greater valve area and hence a larger valve, to discharge a given volume of steam in a given time. Owing to the peculiar construction of the spring or pop valve, the latter rises further from its seat when "blowing," and hence does not re-

quire so large an area. For portable engines, locomotives and marine service the pop valve is particularly well adapted, owing to the absence of the lever and ball.

13. How is the required area of a safety-valve obtained?

Divide the area of the grate in square feet by three, for a spring-loaded, or pop safety-valve, and by two, for the lever and weight valve; the quotient will be the area of the valve in square inches. The following table gives the proper area of the valve for one square foot of grate surface:

Press. by gauge ...	10	20	30	40	50	60	70	80	90	100	110	120
Area sq. inches....	1.2	.79	.58	.46	.38	.33	.29	.25	.23	.21	.19	.17

14. (a) How do you calculate the pressure at which a safety-valve will blow? (b) How is the distance between the center of the ball and the fulcrum calculated? (c) How do you calculate the weight of the ball required?

(a) Multiply the weight of the ball in pounds by the distance between the ball and fulcrum. Call this product A. Multiply one-half the weight of the lever by the distance between the valve and fulcrum = product B. Multiply the weight of the valve and stem by the distance between the valve and fulcrum = product C. Multiply the area of the valve in square inches by the distance between the valve and fulcrum = product D. Add together products A, B and C, and divide by product D; the quotient will be the pressure. (b) Multiply the pressure by the area of the valve and by the distance between the valve and the fulcrum = product E; multiply one-half the weight of the lever by the distance between the valve and the fulcrum = product F; multiply the weight of the valve and the stem by the distance between the valve and fulcrum = product G; add together products F

and G, and subtract the same from product E; divide the remainder by the distance between the center of the ball and fulcrum; the quotient will be the weight of the ball. (c) Add together products F and G and subtract from product E as before. Divide the remainder by the weight of the ball; the quotient will be the distance between the fulcrum and the center of the ball.

15. What is meant by the terms, (a) heating surface, (b) grate-surface, (c) steam-room, (d) atmospheric pressure, (e) latent heat?

(a) All surfaces having water on one side and fire or heated gases on the other. (b) The surface of the grate-bars, or the area of the surface which supports the burning fuel. (c) The space above the water-line, or all space in a boiler not occupied by water. (d) The pressure of the atmosphere which is taken at 14.7 pounds per square inch, and is equivalent to a column of mercury 30 inches high, at sea level. (e) Latent means invisible, not apparent; therefore, latent heat means a quantity of heat which has disappeared, having been employed to produce some change other than elevation of temperature. By reversing that change the quantity of heat which has disappeared is reproduced, and may be ascertained, or measured.

16. How is the pressure of the atmosphere measured? How may a vacuum be measured without a vacuum gauge?

By means of a column of mercury, as in a barometer. If the mercury stands 30 inches high when open to the atmosphere, the pressure may be found by multiplying 30 by .49, (the weight of a column of mercury one inch high) = 14.7 pounds. When applied to a condenser should the mercury

rise but four inches high the pressure in the condenser would be $4 \times .49 = 1.96$ pounds. This would be equal to a vacuum expressed in pounds of $14.7 - 1.96 = 12.74$, and a vacuum gauge would indicate $12.74 \div .49 = 26$ inches.

17. How do you find the number of square feet of heating surface in a (a) horizontal tubular, (b) locomotive, (c) vertical boiler?

(a) Multiply the inside circumference of one tube by the length, both in inches, and by the number of tubes. Divide the result by 144 and the quotient will be the number of square feet of surface contained in the tubes. Multiply two-thirds the circumference of the shell by the length, both in inches, and divide the result by 144; the quotient will be the number of square feet of surface in the shell. From the area of one head subtract the combined area of the tubes and divide by 144; the quotient will be the effective surface in the heads. Add together the three results thus obtained; the sum will be the total number of square feet of heating surface. (b) Add the width of the fire-box to twice its height; multiply this sum by the length = product A. Multiply twice the width of the fire-box by its height, all in inches = product B. Add together products A and B. From this sum subtract the area of all the tubes and the fire-door. Divide the remainder by 144; the quotient will be the number of square feet of surface in the fire-box. The circumference of one tube multiplied by the length, both in inches, and by the number of tubes will give the square inches of surface in the tubes; this divided by 144 will be the number of square feet. The sum of the number of square feet in the fire-box and tubes will be the total heating surface. (c) Multiply the height of the fire-

box by the circumference in inches = product C. From the area of the crown sheet subtract the combined area of the tubes and fire-door = product D. Multiply the inside circumference of one tube by the length or height to the water line, both in inches. and by the number of tubes = product E. Add together products C, D and E and divide by 144; the quotient will be the number of square feet of surface.

18. What is meant by the term horse-power when applied to a steam boiler?

There is, strictly speaking, no such thing as horse-power of a boiler. The term horse-power refers to the measurement of power, or energy produced in a given time. A boiler does not produce energy, therefore the work of a boiler cannot be measured by horse-power. Energy is the product of a given force in pounds multiplied by the distance in feet through which it moves, and horse-power is obtained by dividing the energy thus obtained in one second by 550, in one minute by 33,000, and in one hour by 1,980,000. A boiler contains a force only, therefore the term horse-power is merely relative, and when applied to a boiler conveys to the mind the horse-power of an engine which a boiler of given size is capable of supplying with steam.

19. Which will safely carry the higher pressure, other things being equal, a boiler 72 inches in diameter or one 42 inches in diameter? Why?

A boiler 42 inches in diameter. The amount of surface contained in a boiler 72 inches in diameter is $72 \div 42 = 1.71$ times that in a boiler 42 inches in diameter, therefore, having the same steam pressure in both boilers, the force tending to

pull the plates asunder in the 72-inch boiler will be 1.71 times that in the 42-inch boiler.

20. How far from the shell should the top of the bridge-wall and grates be?

The principal object in the use of the bridge-wall is to form the back end of the furnace, and it should be high enough to retain the coal in the furnace when the deepest fires are being carried on the grates. There is no particular advantage in having the bridge-wall higher than is necessary to accomplish this, let the distance from the shell be what it may. The distance between the shell and grates should never be less than one-half the diameter of the boiler for bituminous coal, nor less than four-tenths the diameter of the boiler for anthracite. The distance from the shell to the top of the bridge-wall will then be from 14 to 20 inches according to the size of the boiler.

21. How do you determine the number of square feet of grate surface required for a boiler?

The grate surface required will vary with the quality of fuel to be burned. Good bituminous coals require the least and slack coals the greatest number of square feet. With the former coal a ratio of 45 to 50 is allowed, and with the latter from 38 to 45. A boiler in which the ratio of grate to heating surface is 45, would have one square foot of grate surface to 45 of heating, therefore if the heating surface is known the grate surface may be found by dividing the heating surface in square feet by the ratio as given above. When the weight of water to be evaporated per hour is known, the grate surface required may be found by dividing the weight of water in pounds by 94, or multiplying by .0106.

22. (a) How do you find the safe-working pressure of a boiler? (b) How thick should the shell of a 72-inch boiler be, to safely carry a pressure of 90 pounds per square inch?

(a) The safe-working pressure may be found by either of the following rules: Rule 1: Subtract the diameter of rivet hole from the pitch of the rivets, and divide the remainder by the pitch of rivets, all in inches, and call this quotient, 1; then multiply the thickness of plate by the tensile strength in pounds and by quotient 1. Divide the product thus obtained by five times the internal radius of the shell, the quotient will be the safe-working pressure. Or by Rule 2: Multiply the thickness of the plate in inches by 16,000 and divide by the diameter of the boiler in inches; the quotient is the safe-working pressure. The thickness of shell is found by multiplying the pressure in pounds per square inch, by the diameter of the boiler in inches, and dividing the product by 16,000; the quotient will be the thickness in inches. (b) By the rule given above the thickness would be $90 \times 72 \div 16{,}000 = .45$ of an inch, the nearest obtainable thickness being seven-sixteenths.

23. What points should receive particular attention when connecting up a water-column, a steam-gauge and a safety-valve?

The column pipes should be of ample size, of extra heavy pipe and never less than one inch in diameter. The upper pipe should enter the dome or steam drum as the case may be; the lower pipe should enter the front head of the boiler at such a height that the bottom of the water glass, (or lower gauge cock) will be not less than one and one-half inches above the top row of tubes. The column pipes should be as

free from bends as possible. Tees should be used instead of elbows, to facilitate cleaning, and care taken to have the lower pipe level. The column should be provided with a blow-off pipe of ample size, closed by a gate-valve. Where the water contains much foul matter or mud, it is advisable to put gate-valves in the column pipes near the column, to secure full pressure when blowing out the lower pipe. The pressure gauge should be located in as cool a place as possible, not too far from the boiler. The gauge pipe should be of such form that a little water may be introduced before screwing the gauge on, so that the gauge will be filled with cold water at all times. Provision should also be made for draining the gauge pipe and gauge during freezing weather, when there is no steam in the boiler. The safety valve should be placed on the top of the dome, or steam drum, having as direct and short a connection as possible. No valve or branch pipe should be placed between the safety valve and boiler. If a lever valve, care should be taken to have the lever and valve-stem work freely, also that the ball is secured to the lever, and will not come in contact with any pipe, valve or other obstruction.

24. *How do you find the commercial rating, or horse-power of a boiler?*

By first finding the number of square feet of heating surface, (see answer no. 17) and dividing by 12, which gives what is known as boiler-makers' rating. If the evaporative capacity of the boiler is given, expressed in pounds of water from and at 212 degrees f. per hour, or at 70 pounds gauge pressure, from feed at 100 degrees f. the boiler h. p. may be found

by dividing the weight of water evaporated by 30 and 34, respectively.

25. *How is the evaporative power of a boiler obtained?*

By multiplying the area of the grate in square feet by the weight of coal burned per hour on one square foot and by 8.2, the product will be the evaporation in pounds per hour.

26. *How are boilers supplied with water—name the various methods. Which do you consider the most economical method?*

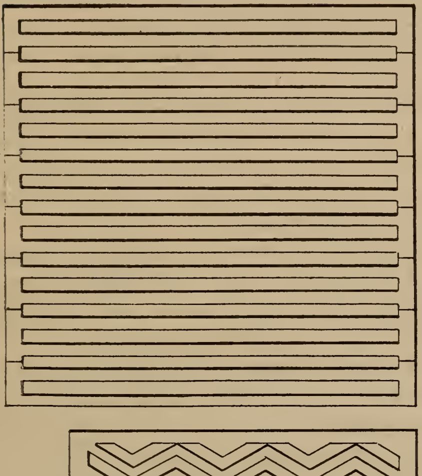
By means of pumps, injectors, and gravity. A belt-driven pump forcing water through a good feed-water heater before it enters the boiler is probably the most economical means of feeding a boiler, all things considered. Next to this comes the duplex direct-acting steam pump, employing a feed-water heater as before. The injector is a very convenient as well as cheap form of boiler-feeding apparatus, but when used without a feed-water heater the economy is but little better than it is with a pump under similar conditions.

27. *What qualities should characterize all methods of feeding boilers?*

Ample capacity, accessibility, reliability, simplicity and the ability to supply the boiler continuously with the maximum amount of water required.

28. *At what temperature does water boil under atmospheric pressure? Does the pressure of steam in a boiler have any effect upon the boiling point, if so what effect?*

At 212 degrees f. When the pressure upon the water is increased, as in a steam boiler, the boiling point is raised, for it requires more heat to overcome the cohesion of its atoms than at atmospheric pressure. At 50 pounds by the gauge



Two Types of Grate-Bar Containing the Same Amount of Air Space.

the boiling point is raised to 298 degrees; at 100 pounds, 338 degrees; and at 150 pounds, 366 degrees.

29. What points should characterize a good furnace grate?

Large air space—at least 55 per cent (see illustration, in which both grates have the same amount of air space)—deep, thin bars, so made as not to warp easily, provision for shaking, and also for dumping when the boilers are crowded, and a poor quality of fuel is in use.

30. About what is the economical limit of coal consumption per square foot of grate per hour with natural draft?

About 24 pounds with a steady load, otherwise from 18 to 20 pounds.

31. (a) What is a chimney? (b) What determines the intensity of the draft? (c) Upon what does the capacity of a chimney chiefly depend?

(a) A vertical flue, usually of iron or brick, for conveying the heated air and combustion gases from the fire to the outer air. It usually extends some distance above the tops of buildings. (b) The height. The intensity of the draft increases directly as the height. (c) The height and area. The capacity of a given chimney varies as the square root of its height.

32. What is the difference between natural, induced and forced draft?

Natural draft is that produced by a chimney alone, and is due to the difference between the weight of a column of the hot gases inside the chimney and an equal column of air on the outside. Induced draft is obtained by placing a fan blower at, or above, the boilers. The uptake from the boilers is connected to the inlet of the blower, and the outlet is car-

ried to the chimney, discharging the gases and heated air into the chimney. Forced draft is obtained by conducting the discharge of a powerful blower to the ash-pit—the air being forced through the fire.

33. What is your theory of the production and prevention of smoke?

Smoke is the volatilized products of the combustion of the fuel, and is invariably the result of incomplete combustion. It is composed chiefly of minute particles of carbon and steam, and is due largely to an excess of air admitted to the fire although in a few cases the production of smoke has been due to an insufficient supply of air to the fire. If the boiler is not crowded, and the draft is good, allowing the coal to coke at the front of the grates, afterwards pushing it back over the incandescent coals, will serve to reduce the volume of smoke. The hollow bridge-wall provided with suitable means for regulating the supply of air also gives good results where there is a strong draft. A small grate area and a very hot fire will reduce the volume of smoke, as will a very large grate area and a slow fire, although the former is the more economical.

34. Explain your method of banking a fire.

An economical manner of banking fires is to push the live coals back against the bridge-wall leaving the forward part of the grates covered with ashes only; then cover the live coals with a moderately thick layer of fresh coal. Fine coal is preferable as the air does not readily pass through it, especially when the draft is diminished by closing the damper, which should be done just before covering the fire with fresh coal. The damper should be left open a very little to avoid the ac-

cumulation of gas in the furnace, and a possible explosion. This method of banking fires saves much time when preparing to start again, as the grates may be quite thoroughly cleaned without disturbing the low fire at the bridge-wall, which is then pulled forward, spread evenly over the grates, and fresh fuel added.

35. Should a boiler be fed intermittently or continuously? Why?

When a boiler is used for heating purposes, and steams very easily, it does not make very much difference whether it is fed continuously or not, but a power boiler should be fed continuously, otherwise the water level becomes low. Aside from the ill-effects of expansion and contraction, and the danger of having the water supply shut off when it is in this condition, when the feed-water is again started it must be introduced in larger quantities than if fed continuously. The feed-water entering the water in the boiler when the volume has been reduced, as at the time for "pumping-up," has a greater tendency to rapidly cool the water in the boiler. This invariably requires heavy firing to maintain the steam pressure. The result is that more coal is burned than would have been necessary had the feed-water been introduced as fast as it disappeared in the form of steam or by a continuous feed.

36. What kinds of boiler-feeding apparatus are most favorable to continuous feeding?

A direct-acting duplex steam pump or one driven by a belt.

37. Should a boiler be fed with hot or cold water? Why?

With hot water. Introducing cold water into a boiler tends

to reduce the temperature of the water in the boiler, particularly in those parts near the opening of the feed-pipe, causing those parts to contract, which strains the plates and seams, more or less severely, according to the temperature and volume of the water introduced.

38. What effect do drafts of cold air have on boilers?

The same as introducing cold feed-water, though the strains produced are frequently more severe, often resulting in leaky tubes, seams and rivets, as well as a waste of fuel.

39. Explain your method of cleaning boilers, and state about how often a boiler should be cleaned?

After shutting down the engine at night draw the fires, close the damper, with the fire and ash-pit doors partly open, allowing the boiler to cool down during the night. In the morning open the damper and ash-pit doors and empty the boiler, then remove the man-hole plate on top and the hand-hole plates from the head of the boiler, and by means of scrapers made for the purpose, proceed to scrape the mud and loose scale to the front end, where it may be removed through the hand-hole. Then enter the boiler through the man-hole, and scrape off all the scale and other accumulations as far as can be reached, seeing that the entrance to the column and blow-off pipe is clear, and lightly tap the braces to make sure they are tight. Then repeat the operation of scraping out below the tubes to remove large pieces of scale, after which the boiler is to be thoroughly rinsed with a hose. The plates are then returned to their places, the blow-off valve closed and the boiler filled with water. When the water makes its appearance in the gauge-glass open the column blow-off and rinse the blow-off pipe and bottom column con-

nections, then start a slow fire under the boiler so as to heat the water gradually until it begins to boil, when the fires may be hurried if need be. If the gauge-glass is properly located as to height, shut off the water when the glass becomes one-fourth full until after raising steam, then raise the water-level to the height required. The exact length of time a boiler may run without cleaning will depend upon the purity of the feed-water and the number of hours the boiler is in use during the day or week. The time for cleaning must be decided in each case. Boilers in cities located on such bodies of water as the great lakes are usually cleaned once a month, when running ten hours a day. If river water is used, such as the Ohio, Mississippi and Missouri rivers, a boiler running ten hours per day should be cleaned every two or three weeks. Boilers should be entered and scraped as thoroughly as possible, and carefully inspected as often as four times a year regardless of the location.

40. At what height should the water-line be maintained when running?

This will depend upon the location of the water column and gauge-glass, as well as the amount of steam room in the boiler. The depth of water over the tubes should not be less than six inches in boilers supplying steam for engines. When the water-level is six inches above the top of the upper row of tubes, should the glass be half full, then this is the point at which the level should be maintained, which corresponds to two and one-half gauges. In this case, should anything occur to the pump or injector, it would allow from 15 to 20 minutes in which to get the feed started again before the water-level would fall sufficiently low to cause a shut-down.

41. If the water supply should be interrupted for an indefinite length of time, how and what would you do?

If the length of time the supply is to be stopped cannot be ascertained to within five or ten minutes, the engine should be shut down immediately. In any case the water-level should not be allowed to fall below one and one-half gauges before stopping the engine. If heavy fires are carried and the steam pressure increases rapidly, close the ash-pit doors and damper immediately upon the stoppage of the water supply. If the boiler contains plenty of water, allow the engine to run until the water-level reaches the second gauge; the steam pressure will then have been lowered so that stopping the engine will not cause the pressure to rise rapidly nor dangerously high. Should there not be enough water in the boiler to allow the pressure to be lowered in this manner, the fire may be covered with ashes, preferably wet, and the damper and ash-pit doors closed as before.

42. How often should the blow-off valve be opened?

From two to four times a week where the feed-water is passably pure, but when using river water it should be opened at least once a day, preferably in the morning before a hot fire is had under the boiler. At this time much of the matter held in suspension in the water while the boiler is in operation, will have settled to the bottom and may be blown out, or may be allowed to run out.

43. If you were obliged to stop the engine with a heavy fire in the furnace how would you proceed? Why?

Close the damper and the ash-pit doors and start the pump or injector to prevent the pressure from becoming dangerously high. If the water rises too high before the pres-

sure ceases to rise, open the surface blow-off if there is one, if not, the boiler blow-off valve, and lower the water-level in this way, allowing the feed to continue until the fire dies down and the pressure ceases to rise. If it is impossible to keep the pressure down by feeding, when both the damper and ash-pit doors are closed, the fire may be covered with wet ashes, as in the case of interrupted water supply. The wet ashes, however, are to be used as a last resort.

44. *Illustrate your method of obtaining the percentage of saving by feeding a boiler with hot water, instead of cold.*

The percentage of saving may be found by the following rule: Divide the difference in the total heat of the water above 32 degrees before and after heating, by the total heat required to convert it into steam from the initial temperature. There are 1,180.7 heat units above 32 degrees in a pound of steam at 80 pounds gauge pressure, or 1,180.7 —(60 — 32) = 1,152.69 above 60 degrees, which is the initial temperature of the water. The boiler would have to supply 1,152.69 heat units to make a pound of steam at 80 pounds pressure from water at 60 degrees. In raising the water to 140 degrees the heater supplies 140 — 60 = 80 heat units and the percentage of saving is 80 ÷ 1,152.69 = 6.94 per cent.

45. *To what would you first direct your attention upon entering a strange boiler room, or upon arriving in the morning?*

The water-level in the boiler, and when taking charge of a strange boiler the source of the water supply and the means provided for feeding the boiler should receive attention before starting a fire. The true water-level may be ascertained

by first opening a gauge cock above the water-level indicated in the glass, to allow air to enter the boiler. Then open the column blow-off and the drip to the gauge-glass; upon closing them again the level indicated by the glass should correspond with that found by opening the gauge cocks.

46. Why do boiler tubes require cleaning, and about how often?

The soot that collects in them is a non-conductor of heat, therefore when the surface of the tubes is covered with soot only a portion of the heat of the gases passing through them can get to the water surrounding the tubes. The remainder is carried to the chimney. A compact layer of soot in a boiler-tube, one-eighth of an inch thick, will cause as much waste of fuel as three-thirty-seconds of an inch of scale. When burning bituminous coal, soot will collect to the above depth in about ten hours, therefore, in order to have reasonably clean tubes at all times it is usually necessary to blow or scrape them at least once a day.

47. How do you ascertain the true water-level in a boiler when foaming? When priming?

Foaming is usually caused by the presence of grease in some form. Therefore an endeavor should be made to change the water in the boiler as rapidly as possible. Slacken the speed of the engine, and start the pump or injector until the water-level will allow of from two to four inches being blown down, preferably by means of the surface blow-off, as much of the grease will be at the surface of the water. Continue this operation until the water in the gauge-glass comes to rest when the true level may be ascertained as in answer 45. Priming is caused by insufficient steam room in the

boiler. The water-level in this case should be maintained as low as possible and yet be safe. A drum of moderate size or a large separator may be placed in the steam-pipe close to the engine. This will tend to increase the steam-room and at the same time will trap the water on its way to the engine should the boiler prime again.

48. If the water-level should become dangerously low, how would you proceed?

Draw the fire immediately. Allow the engine to continue running, and prevent water from entering the boiler in any quantity. Do not open or close the valves nor tamper with the safety-valve. Allow the engine to run until it stops from lack of sufficient pressure, then close the throttle-valve. When the furnace has cooled down to about the same temperature as the boiler, the water-level may be raised very gradually until water appears in the glass, when it may be more rapidly filled, and the fire started.

49. When steam in large quantities and at moderate pressures is required—often suddenly—what type of boiler would you select?

The horizontal return tubular boiler, on account of the large steam-space and water-surface at the water-line in this type of boiler, and because it is a comparatively cheap, economical and safe boiler.

50. If steam in large quantities and at high pressure is required what type of boiler would you select?

The water-tube boiler, in whatever form, would best meet the conditions existing. Owing to the small volume of water contained in each tube, it is converted into steam very rapidly, and as the tubes are of small diameter they are capable

of carrying a very high safe-working pressure. These qualities render the water-tube boiler particularly well adapted to generating steam rapidly, and safely at high steam pressures.

51. Is boiler scale injurious to a boiler, and does it affect the economical generation of steam?

Yes; in preventing the water from coming in contact with the plates and tubes, the latter are heated to a much higher temperature than would otherwise be possible, and too high for the good of the metal. Thick scale on the surface of a boiler causes unequal expansion of the plates and tubes, which results in leaky tubes, seams, rivets, and largely accounts for blisters and bagging, due to overheating at these parts. Scale retards the passage of heat from the fire and gases, to the water, thereby interfering with the rapid generation of steam. The percentage of coal required to overcome the loss due to boiler scale is not definitely known.

52. Explain various methods of removing and preventing scale.

Kerosene oil removes old scale very effectually. About one-half pint of kerosene oil per day fed continuously into the feed-water will be found sufficient to remove scale as fast as it can be taken care of, by cleaning the boiler, and without danger of accumulating and causing serious over-heating. Scale may be to some extent, prevented by the use of a good compound, provided the water has been analyzed and the compound prepared particularly for the water being used. Mechanical boiler cleaners may be used with good effect, but with either method a boiler should be thoroughly cleaned at regular and frequent intervals if the full effect of the tendency to prevent scale-forming, is to be realized.

53. What is a feed-water heater and for what is it used? What is the difference between an open and a closed heater?

A machine or apparatus for heating the feed-water by utilizing a portion of the heat in the exhaust steam, thus returning to the boiler a certain number of heat units that would otherwise go to waste. An open heater is one in which the exhaust steam comes in contact and mixes with the water to be heated. In a closed heater the exhaust steam is kept separate from the water to be heated, the water usually passing through pipes surrounded by steam.

54. To what temperature may water be heated in a closed heater, using exhaust steam?

To about 210 degrees f. provided the heater is of the proper size.

55. Where should a feed-water heater be located and how should it be connected up with reference to the arrangement of pipe?

It should be placed as near the engine as practicable to insure as short an exhaust connection to the engine as possible, and steam of the highest temperature possible in the heater. As steam parts with its heat more rapidly than water, it is better to allow the water to travel the greater distance. The feed-pipe should be as straight as possible, and provided with a gate-valve next to the boiler, then a check-valve, and a second gate-valve next to the heater, also a gate-valve in the inlet pipe close to the heater.

56. How would you determine the size of a heater required for an engine of given h. p.?

Allow one-half square foot of pipe surface for one h. p. developed in the engine.

57. Which do you consider the better method, pumping hot water from the heater into the boiler, or forcing cold water through the heater?

A pump works much better and lasts longer, with fewer repairs, when pumping cold water, and may raise water from a well or cistern, which is impracticable when pumping hot water. In the latter case the pump must be located below the source of water supply. For these reasons it is preferable to pump cold water through the heater.

58. What causes the water to flow into the water cylinder of a pump? Does the temperature of the water have any influence upon the height to which a pump can raise it by suction?

The pressure of the atmosphere. The plunger of the pump removes the pressure of the air from the surface of the water in the suction pipe, when the water is forced upward and into the pump cylinder by the pressure of the air on the surface of the water outside the pipe. As the temperature of the water increases, the height is decreased. Water at 60 degrees f. can be raised by suction to a height of nearly 28 feet. A temperature of 140 degrees f. corresponds to a vacuum of 23.5 inches of mercury, or an atmospheric pressure of 11.5 pounds per square inch. A column of water 2.26 feet high weighs one pound at 140 degrees, therefore a pressure of 11.5 pounds would support a column 25.99 feet high.

59. How is the capacity or duty of a pump expressed?

In foot-pounds of work per million heat-units furnished by the boiler for large pumping engines, and in gallons per minute, or per hour, for medium and small sized pumps.

60. What information would you require in order to determine the proper size of a steam pump?

The volume of water in cubic feet or gallons to be moved in a given time, the temperature of the water and the height to which it must be raised; also the length, and number of bends in the suction and delivery pipes.

61. What is an injector, and what advantages has it over a pump?

An injector is a machine for raising and forcing water by means of a jet of steam. It is smaller than a pump of like capacity, has no moving parts, requires the minimum of space, heats the feed-water and costs less than a pump of the same capacity.

62. How do you find the number of gallons of water that a pump of given size is capable of raising in a given time?

Multiply the square of the diameter of the water cylinder in inches by four, and by the piston-speed in feet per minute; divide the result by 120; the quotient will be the number of gallons per minute.

63. Can a pump force water against a pressure higher than that of the steam used to run the pump? How?

Yes. A pump having six-inch steam cylinders and four-inch water cylinders, will be capable of forcing water against a pressure as much greater than that of the steam, as the area of a six-inch piston is greater than the area of a four-inch piston. The area of a six-inch piston is 28.27 square inches, and that of a four-inch piston 12.56 square inches, therefore the water pressure may be $28.27 \div 12.56 = 2.25$ times the steam pressure.

64. Why will an injector force water into a boiler, when the pressures in the steam pipe to the injector and boiler are equal?

The mingled jet of steam and water rushes into the vacuum formed by the condensation of the steam with such velocity that the momentum acquired carries it into the boiler.

65. (a) What does a pressure-gauge indicate? (b) Should a gauge contain dry steam or water? Why?

(a) The pressure upon one square inch of surface. (b) Water. The bent tube which forms the spring in a pressure gauge moves very slightly when the pointer indicates ordinary pressures, and tends to lose its elasticity and become "set" when subjected to the temperature of steam.

66. If the pointer of a pressure-gauge fails to return to zero when there is no pressure in the boiler, what would you do?

If the discrepancy exceeds three or four pounds, the gauge should be tested by one known to be correct and the pointer adjusted accordingly; if less than three pounds the pointer may be removed and set at zero before admitting pressure to the gauge.

67. (a) What is an engine? (b) What do you understand by the term high-speed engine? (c) Slow-speed engine?

(a) A machine for transforming the expansive force of steam into energy or work. (b) An engine running at a high speed of revolution—a fast running engine. (c) An engine running at a slow speed of revolution. A slow-speed engine may have as high a piston speed as the high-speed engine, therefore in this respect there would be no difference, al-

though in speed of revolution one engine might run twice as fast as the other.

68. (a) How do you denote the direction in which a stationary engine is running? (b) How could you tell in which direction an engine will run before the engine is started?

(a) "Over" and "under." If the crank-pin, when leaving the dead-center nearest the cylinder, moves *over* the shaft in reaching the opposite dead-center the engine runs "over," if it moves *down* and passes below the center of the shaft, then it runs "under." A locomotive engine when running forward or ahead, runs "under." (b) By an inspection of the eccentric, having first ascertained the kind of valve and valve-gear employed.

69. How is the work performed by an engine, expressed?

In foot-pounds and horse-power.

70. What is meant by the term horse-power, and how do you find the horse-power of an engine?

One horse-power is equivalent to 550 foot-pounds per second (raised one foot high in one second) or 33,000 foot-pounds per minute or 1,980,000 foot-pounds per hour. The number of foot-pounds of energy generated by an engine may be found by multiplying the area of the piston in square inches by the m. e. p., and by the piston-speed in feet per minute. The product will be the number of foot-pounds per minute, which if divided by 33,000 will give the number of horse-power.

71. What do you understand by clearance in an engine?

All the steam space between the valve and cylinder and between the cylinder head and piston when the latter is at the end of the stroke. Piston-clearance is the distance the

piston clears the cylinder head when the crank is on the dead center.

72. State a method by which the percentage of clearance in an engine may be obtained.

First secure a pail or other vessel having straight sides, that is, not tapered. Find the number of cubic inches contained in the pail for one inch in depth. Then place the crank on the dead center and move the valve enough to close the lead opening. Take out one of the indicator plugs and fill the clearance space full of water. Draw off the water through the cylinder cock into the pail, and multiply the volume of the pail for one inch in depth by the depth of water. The product will be the number of cubic inches contained in the clearance space. Multiply the area of the piston in square inches by the length of the stroke in inches, which will give the number of cubic inches in the cylinder, then divide the volume of water in the pail by the volume of the cylinder; the quotient will be the percentage of clearance.

73. What is meant by piston displacement? How do you find it?

The volume of the cylinder, or the space passed through by the piston during one stroke. Multiply the area of the piston by the length of the stroke, both in inches; the product will be the piston displacement in cubic inches.

74. How do you find the area of a piston? Also the piston speed?

Square the diameter and multiply by .7854. Multiply the length of the stroke in inches by two and divide the product by 12. This gives the piston travel for one revolution, then multiply by the number of r. p. m.; the product will be the

piston speed in feet per minute. If the length of the stroke is in even feet, multiply the length of the stroke by two and by the number of r. p. m., and the result will be the piston speed in feet per minute.

75. *How do you ascertain the m. e. p., terminal pressure, and number of expansions in an engine cylinder?*

To obtain the m. e. p. add one to the hyperbolic logarithm of the ratio of expansion, divide the sum by the ratio of expansion and multiply the quotient by the initial pressure; from this subtract the back pressure. The remainder will be the m. e. p. The m. e. p. may be estimated by multiplying the initial pressure by the following decimals corresponding to the given cut-off, and subtracting the back pressure:

Cut-off,	1/8	1/4	1/3	3/8	1/2	5/8	2/3	3/4	7/8
Decimal,	.48	.59	.67	.74	.84	.91	.93	.96	.99

Divide the initial pressure by the number of expansions; the quotient will be the terminal pressure. Divide the length of the stroke, by the distance the piston has moved when cut-off occurs plus the clearance; the quotient will be the number of expansions.

76. *What is the difference between a throttling engine and an automatic cut-off engine? A simple and a compound engine?*

In a throttling engine the cut-off is usually fixed, the speed of the engine being governed by means of a fly-ball governor in the steam pipe, which varies the pressure of steam admitted to the cylinder as the load changes. In an automatic cut-off engine, the pressure of steam remains the same, the speed being governed by varying the quantity of

steam admitted to the cylinder, and this is accomplished by the governor which changes the point of cut-off to suit the load. A simple engine is a single-cylinder engine exhausting into the atmosphere. If it is a condensing engine, then it is called a simple condensing engine. A compound engine is provided with two or more cylinders. The steam, after performing a certain amount of work in the first cylinder, passes into the second and performs additional work. From the second, or low-pressure cylinder, it passes to the condenser. If no condenser is used it is a compound non-condensing engine.

77. *How do you find the h. p. of a compound condensing engine?*

Find the m. e. p. in both the high and low pressure cylinders, either directly from an indicator diagram, or by the preceding method. Add them together and divide the sum by the area of the low-pressure piston. The quotient will be the equivalent m. e. p. if all the work was done in the low-pressure cylinder. Then proceed to find the h. p. as directed in answer 69.

78. *What advantages has a compound over a simple engine?*

The principal advantage to be had in the use of the compound engine is a reduction in cylinder condensation. The range of temperature in each cylinder is considerably less than can be obtained in a single cylinder engine when employing the same number of expansions. When thus reducing the rate of cylinder condensation the steam may be expanded to a much lower pressure without loss, and consequently with a gain in power. Therefore a compound engine

may develop more power with the same weight of fuel, or the same power with less fuel than the single-cylinder engine.

79. How do you obtain the number of expansions in a compound engine?

Obtain the number of expansions in the high and low pressure cylinders separately (see answer 75) and multiply one by the other, the product will be the number of expansions.

80. Explain your method of placing an engine on the exact dead-center.

Turn the engine crank around until the cross-head is about one-half inch from the end of the stroke. With a scriber make a mark on the cross-head, extending it to the guide. Drive a wire nail through one end of a thin strip of wood of convenient length and place the strip in a vertical position, with one end on the floor close to the rim of the fly-wheel (or pulley) and with the point of the nail make a mark on the rim of the wheel. Now turn the crank over the center and back on the return stroke until the line on the crosshead again coincides with the line on the guide. With the strip of wood in the same place and position make another mark on the rim of the wheel and with a flexible scale or pair of dividers, find the exact center between the two marks on the rim of the wheel and make a third mark at this point. Now, with the strip of wood in the same place and position as before, turn the engine crank around until the central or third mark made on the rim of the wheel reaches the point of the nail, when the engine will be on the exact dead-center.

81. How would you proceed to line-up an engine?

Remove the cylinder-head, piston and rod, stuffing-box

gland, crosshead and connecting-rod and turn the crank to the lower quarter. First place a level on the shaft and level it, if need be, by raising or lowering the outboard bearing, as the case may require. Fasten one end of a stout cord or better still, a fine wire to some object beyond the crank and pass the other end of the wire through the stuffing-box and cylinder and fasten to some object as before. With a pair of inside calipers take the distance between the walls of the cylinder and wire at each end of the cylinder and also at one or more intermediate points, for the purpose of bringing the wire into the exact center of the cylinder. When the wire occupies a perfectly central position throughout the length of the cylinder, turn the crank around until the crank-pin just touches the under side of the wire. When the pin occupies this position the distance from the wire to the inside of the shoulder or collar on the pin should be the same on both sides of the wire. If it is not, equalize the distance by moving the outboard bearing slightly, as the case may require. Now turn the crank around and bring the pin up to the wire at the opposite center. Again measure the distance from the wire to the inside of the collar or shoulder as before, which should be the same as at the opposite end. If the engine is fitted with locomotive guide-bars, or a single bar-guide, the distance from the wire to the guide should be taken with the calipers at each end of the stroke, equalizing the distance of the bar from the wire by slightly moving the guides as the case may require. Should the shaft be much out of line, requiring considerable movement of the outboard bearing, it would be advisable to remove the quarter-boxes and scrape them to an even bearing, otherwise the shaft in its new position will be liable to bear

very heavily at the ends of the quarter-boxes only and cause excessive heating. Replace all the parts removed and make the necessary adjustment with the crank on the dead-center. Turn the engine to the opposite dead-center and make sure that the crank passes the dead-center easily.

82. What is meant by the terms (a) force, (b) energy, (c) power?

(a) A force is that which tends to produce motion, as the pressure of steam in a steam boiler. (b) Energy is represented by the product of a force multiplied by the distance through which it moves regardless of the time required to move that distance. (c) Power is energy produced in a given time as per second, minute or hour, and like energy, is expressed in foot-pounds. (For horse-power see answer 69).

83. What does an indicator indicate? How?

The pressure of steam in an engine cylinder, and at all points in the stroke of the piston. By a pencil carried at the extremity of the pencil lever which, when pressed against the card on the paper drum, traces a diagram. The vertical distance measured from a line called the atmospheric line to any point in the line forming the diagram when multiplied by the number of the spring used, represents the pressure of steam in the cylinder at that point in the stroke of the piston; the pressure thus indicated being above the pressure of the atmosphere.

84. How is the m. e. p. obtained from an indicator diagram?

Divide the diagram into a number of equal parts lengthwise, ten for ordinary work, and with a scale corresponding to the spring with which the diagram was taken, measure the

pressure along the center of the space between each of these divisions; that is, between the full lines or ordinates. This pressure must be measured between the lines of the diagram, whether the engine is condensing or non-condensing, and not from the atmospheric or any other line. Add together the pressures obtained at each ordinate, and divide the sum by ten, if the diagram is divided into ten spaces; the quotient will be the m. e. p. When the area of the diagram in square inches is known, the m. e. p. is obtained by dividing the area by the length of the diagram, then multiply the quotient by the number of the spring used when the diagram was taken.

85. Describe an engine-room method of calculating the water consumption from indicator diagrams.

13,750 divided by the m. e. p. will give the number of cubic feet of steam per h. p. per hour used by the engine if steam were admitted during the full stroke of the piston. The above quotient must be multiplied by that part of the stroke completed (after cut-off occurs) where the water rate is to be computed, expressed in decimal parts of the stroke, plus the percentage of clearance, in order to get the volume of steam used when cutting off at less than full stroke. The volume of steam thus obtained multiplied by the density or weight of one cubic foot of steam corresponding to the pressure at the point in the stroke where the water consumption is to be computed, will give the water consumption for the forward stroke. On the return stroke some steam is saved by compression. This is found by dividing the 13,750 by the m. e. p. as before, and multiplying by the percentage of the return stroke uncompleted at the point where the saving is to be computed, plus the percentage of clearance. The product

will be the volume of steam saved, which multiplied by the density of the steam corresponding to the pressure at the point selected, will give the weight of the steam saved. Subtract the latter from the former result, the remainder will be the number of pounds of water (steam) used per h. p. per hour.

86. Can the exact weight of steam used by an engine be calculated by means of an indicator diagram? If not, why not?

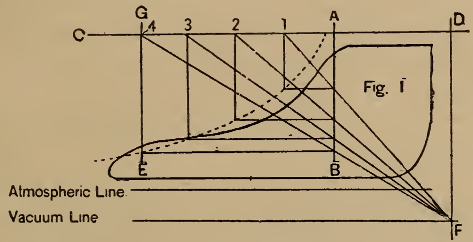
No. An indicator diagram shows the pressure in an engine cylinder, not the volume of steam admitted. When

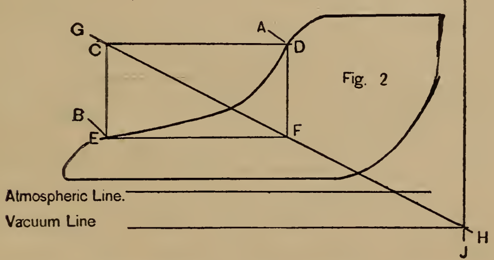
Percentage of Loss by Cylinder Condensation.

Percentage of Stroke Completed at Cut-off.	Simple Engines.	Compound Engines. H. P. Cylinder.	Triple Expansion Engines, H. P. Cylinder.
5	42	..	..
10	34	26	..
15	29	24	22
20	26	22	20
30	22	18	16
40	18	15	13
50	14	12	10

exhaust takes place the walls of a cylinder are at a somewhat lower temperature, owing to the low pressure of the exhaust steam. The incoming steam heats up the cylinder walls which results in a portion of the steam being condensed, but as this loss is instantly made up by live steam, the pressure remains the same, therefore the indicator cannot show the volume of steam condensed, nor any variation in pressure. Cylinder condensation increases as the cut-off becomes

shorter, or occurs earlier in the stroke, for the steam in the cylinder is then expanded to a lower pressure and consequently has a lower temperature. The percentage of steam lost by cylinder condensation is given in the table on the preceding page.





87. Describe a method of drawing the hyperbolic curve on an indicator diagram?

First draw horizontal line *C D*, Fig. 1, parallel to the atmospheric line. Draw perpendicular, *A E* placing the point *A* as near the point of cut-off as possible. Divide the line *C D* into any number of equal parts, 1, 2, 3, 4, etc., and from

these points draw diagonals to *F* at the intersection of the clearance and vacuum lines. From line *C D* let fall *G E* and from *G E* draw lines parallel to the atmospheric line meeting line *A B* at the intersection of the diagonals running to *F*. From the points 1, 2, 3, 4, etc., drop perpendiculars to the several horizontal lines. The point of intersection of the perpendiculars with the horizontal lines from *G E* to *A B* marks the path of the hyperbolic curve, which is shown by dotted lines.

88. Describe a method of obtaining the clearance in an engine by means of a diagram.

Select a point on the expansion curve as at *A*, Fig. 2, and also at *B* before release commences. Draw lines *C D* and *E F* parallel to the atmospheric line. Draw perpendiculars *E C* and *F D* and draw the diagonal *G H*. At the point where the line *G H* intersects the vacuum line raise the perpendicular *I J*. The distance between the lead line of the diagram and the perpendicular *I J*, represents the clearance; the width of this space divided by the length of the diagram will give the percentage of clearance.

89. What is a condenser, and why are condensers attached to steam engines?

An appliance in connection with a steam engine for condensing the exhaust steam, thus producing a partial vacuum in the cylinder. The removal of the resistance (atmospheric pressure) to the movement of the piston, tends to increase the m. e. p. and consequently the speed of the engine. If the load remains the same the cut-off will be shortened and a certain amount of steam will be saved at each stroke. On the other hand, when the m. e. p. is increased by

removing the atmospheric resistance to the piston, it will require a heavier load on the engine to maintain a uniform speed, therefore more power will be developed. The removal of the pressure of the atmosphere by the condensers may be made to serve three purposes, first, a saving in fuel when the load remains constant; second, increased power when the load is increased, so as to maintain a uniform speed with the higher m. e. p., and third, in providing pure water for the boiler when a surface condenser is employed and the feed is taken from the hot-well.

90. How many types of condensers are there? Name them?

There are five types of condensers in use. The surface condenser in which the steam and condensing water are kept separate. The jet condenser in which the injection water mingles with the steam to be condensed. The injector-condenser which employs the principal of the exhaust injector The siphon condenser in which the condensing water is raised to a height of about 30 feet, and descending through a "tail" pipe produces a vacuum. The two latter types require no air-pump. The air-cooled condenser in which a current of cold air is used instead of water, and resembles the surface condenser.

91. In case the vacuum gauge should fail, how could the vacuum be measured?

By means of a column of mercury, as in a barometer. When the tube containing the mercury is open to the atmosphere the latter will reach a height of about 30 inches, and as a column of mercury one inch square and one inch high weighs .49 of a pound, the pressure supporting 30 inches is

.49 × 30 = 14.7 pounds per square inch. Now, if the tube is connected to the condenser, and the mercury stands 3.5 inches high, the pressure supporting it is 3.5 × .49 = 1.7 pounds per square inch, therefore the pressure removed from the condenser will be equal to the difference between the pressure of the atmosphere and that in the condenser, or 14.7 — 1.7 = 13 pounds per square inch. The vacuum gauge indicating the absence of pressure in the condenser, which is usually expressed in inches of mercury would show 13 ÷ .49 = 28 inches vacuum. (See answers to questions 16 and 58).

92. How do you find the number of h. p. that may be transmitted by a single belt 20 inches wide?

By the following rule: Multiply the width of the belt in inches by the velocity in feet per minute and by 48; divide the product by 33,000, the quotient will be the h. p. A belt 20 inches wide, running 2,500 feet per minute, will transmit; 20 × 2,500 × 48 ÷ 33,000 = 72.7 h. p. For double belts multiply the above result by 1.3, thus 72.7 × 1.3 = 94.5 h. p. for a double belt. The rule for finding the width of a belt is: 550 multiplied by the number of h. p. to be transmitted and divided by the speed in feet per minute, will give the width in inches, thus 94.5 × 550 ÷ 2,500 = 20 inches. For single belts multiply the above result by 1.2. To find the length of a belt when closely rolled, add the diameter of the roll and the eye (in inches) together, multiply the sum by the number of turns or coils in the roll, and by 1309; the product will be the length in feet. To find the weight of a belt, multiply the length in feet by the width in inches, and divide the product by 13 for single and eight for double belts.

93. How are the speed and diameter of driving and driven pulleys calculated? Give a rule.

Rule for finding the speed of a driven pulley: Multiply the diameter of the driver in inches by the number of r. p. m., and divide by the diameter of the driven. To find the speed of the driver: Multiply the diameter of the driven by the number of r. p. m., and divide by the diameter of the driver. To find the diameter of the driver: Multiply the diameter of the driven by the number of r. p. m., and divide by the r. p. m. of the driver. To find the diameter of the driven: Multiply the diameter of the driver by the r. p. m. and divide by the r. p. m. of the driven.

94. How many square feet of surface are there in a tube three inches in diameter and ten feet long?

The number of square feet in a tube of any size may be found by multiplying the diameter in inches by 3.1416 and by the length in inches, which will give the number of square inches of surface; this divided by 144, the number of square inches in one square foot, will give the number of square feet. A pipe three inches in diameter and ten feet long will contain $3 \times 3.1416 \times (10 \times 12) \div 144 = 7.85$ square feet.

95. How many feet of three-inch pipe would be required to obtain 150 square feet of surface?

The number of square feet of surface required, divided by the square feet contained in the pipe for one foot in length, will give the number of feet of pipe. A pipe three inches in diameter has $3 \times 3.1416 \times 12 \div 144 = .785$ of a square foot for one foot in length, therefore to obtain 150 square feet will require $150 \div .785 = 191$ feet of pipe.

96. How is the required volume of condensing water calculated?

Multiply the weight of the steam to be condensed by the heat units given up by one pound of steam in condensing, and divide the product by the rise in temperature of the cooling water. Taking steam at 20 pounds pressure by the gauge, initial and final temperature of cooling water at 60 and 108 degrees respectively and the weight of steam condensed at 1,000 pounds, the quantity of cooling water will be $1{,}193 \times 1{,}000 \div (108 - 60) = 24{,}854$ pounds, or $24{,}854 \div 1{,}000 = 24.854$ times the weight or volume of the steam condensed.

97. What is a receiver in an engine? What is a separator?

A receiver is a vessel or chamber used in connection with compound engines, into which the exhaust steam from the high-pressure cylinder is admitted and from which the low-pressure cylinder takes its supply. A separator is an appliance used to remove the entrained water from the steam pipe of an engine.

98. How do you calculate the gain in power that may be had by adding a condenser?

Divide the pressure in pounds corresponding to the inches of mercury shown by the vacuum gauge, by the m. e. p. plus four when running non-condensing. If the vacuum gauge shows 26 inches of mercury and the m. e. p. is 34 pounds per square inch, the increase in power is $26 \times .49 \div 28 = 38.5$ per cent.

99. How do you calculate the saving in steam due to a condenser?

To the m. e. p. non-condensing add three pounds. In the

table of mean and terminal pressures find the cut-off that will produce this mean pressure (absolute), then subtract the cut-off so found, expressed in decimal parts of the stroke from that when running non-condensing, and divide the remainder by the latter cut-off, the quotient will be the percentage of steam saved. M. e. p. non-condensing is 34 pounds per square inch at three-eighths cut-off, and $34 + 3 = 37$ pounds at five-sixteenths cut-off when condensing. The saving in steam is $.375 - .3125 \div .375 = 16.9$ per cent.

100. How do you find the weight of water that may be evaporated by a given weight of coal?

Coal containing little or no incombustible matter will yield about 14,500 heat units per pound. If there is 12 per cent of incombustible matter, there will be 88 per cent of 14,500 heat units available for steam making, or $14{,}500 \times .88 = 12{,}776$ heat units. It requires 966 heat units to convert one pound of water into steam, from and at 212 degrees f. Therefore if there were no loss at the boiler, 12,776 heat units would evaporate $12{,}776 \div 966 = 13.22$ pounds. If the boiler evaporated 10 pounds of water per pound of coal it would have an efficiency of $10 \div 13.22 = 75.6$ per cent, a figure closely approximated but seldom reached in practice.

101. What is the meaning of the following terms: Lap, lead, admission, cut-off, expansion, exhaust or release, compression, and pressure of compression?

See pages 4 to 11.

102. How would you proceed to set a plain D slide-valve?

See page 21.

103. What do you understand by the terms: Initial

pressure, average pressure, terminal pressure, back pressure and mean effective pressure?

By initial pressure is understood the pressure of the steam in an engine cylinder at the commencement of the stroke and is equal to the boiler pressure, minus the losses due to friction and condensation in the steam pipe between the boiler and engine and also the loss in pressure due to wire-drawing at the throttle valve if such exists. The average pressure represents a mean or average between the initial pressure and that at the point of release, and is obtained by adding together the pressures obtained at different points in the stroke and dividing the sum by the number of points at which the pressure was obtained. See page 150. By terminal pressure is meant the pressure of steam in the cylinder at the end of the stroke or at the point where the exhaust valve opens. See page 146. By back pressure is meant the pressure of steam in the cylinder which opposes the movement of the piston and is usually due to a portion of the steam used during the previous stroke remaining in the cylinder. In non-condensing engines the back pressure is measured from the atmospheric line, or above the pressure of the atmosphere, and in condensing engines from a perfect vacuum. The mean effective pressure in any engine is equal to the average pressure minus the back pressure.

104. What do you understand by the term vacuum?

A vacuum is said to exist when the pressure of the atmosphere has been removed; a vessel from which the air has been expelled and the pressure therein reduced to a point below that of the atmosphere.